The Angle Orthodontist

October • 1958

Published Quarterly by
The Edward H. Angle Society of Orthodontia

Published Quarterly by the
EDWARD H. ANGLE SOCIETY OF ORTHODONTIA
Zuelke Building, Appleton, Wisconsin
Subscription Rates: $6.00 per year, Canada $6.25,
other foreign countries $6.50.

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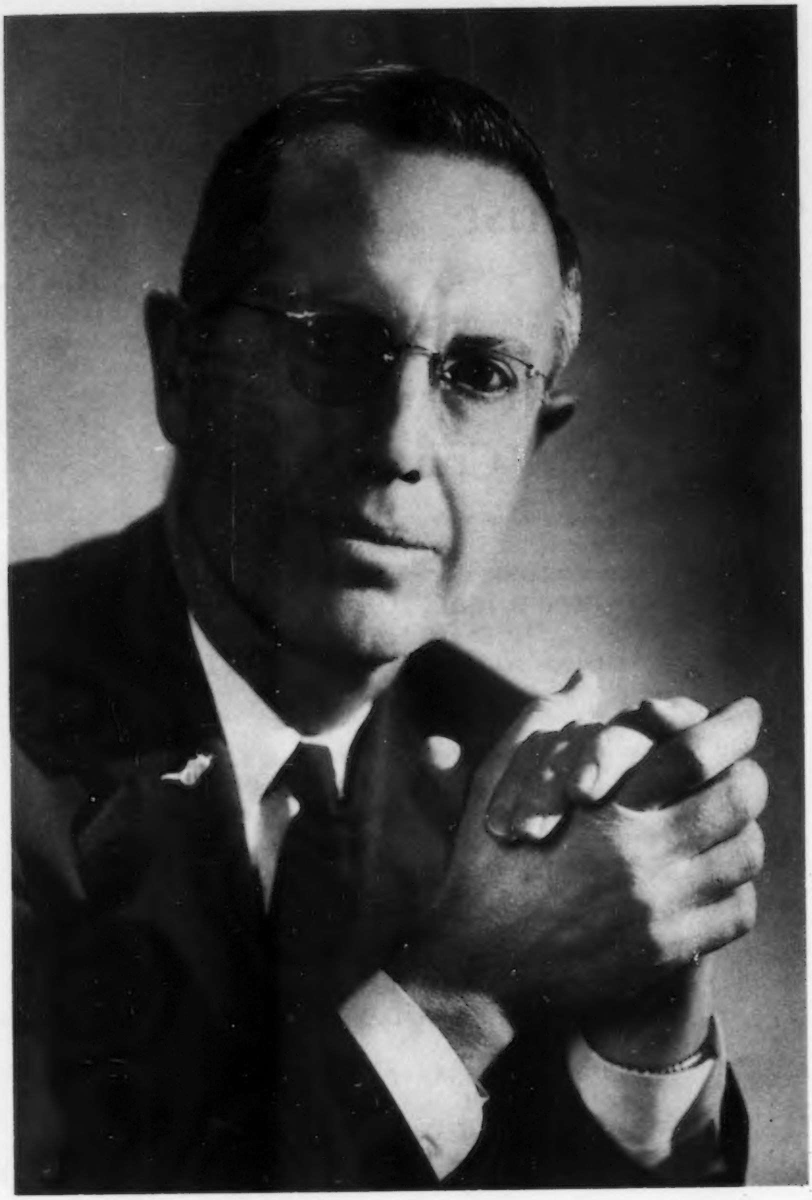
Volume 28, Number 4

Contents



LYNN C. WILKINSON

1905 - 1958

A Cephalometric Evaluation Of Class II, Division 2*

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Introduction

Twenty-four years ago the Eastern Component presented before this society a paper entitled *"A Clinical Study of Cases of Malocclusion in Class II, Division 2."*[6] This paper was a clinical evaluation of the problems associated with this type of malocclusion and the thoughts which were prevalent at that time concerning its etiology and treatment. The current endeavor was undertaken to determine whether the advances and changes which have been made in the last twenty five years have materially altered our thinking and procedures associated with this situation.

Twenty-five years ago cephalometric roentgenography was in its infancy and the information presented at that time was based upon models, facial photographs, and some anthropometric measurements. The advent of cephalometrics has changed our thinking in some phases of orthodontics and has given factual credence to some of our other thoughts. This portion of the Class II, Division 2 symposium is not to be considered as a research project but rather as a grouping of thoughts on the morphology of the Class II, Division 2 problem from a radiographic standpoint. This has been done in an effort to further clinical diagnosis and aid in the planning of treatment.

The first sentence of the 1933 report states, "In reviewing the literature in an effort to find data concerning this type of malocclusion one is struck by the relatively small amount available."[6] This statement remains just as true today as it was then. In the field of cephalometrics there have been some forty types of analyses promulgated, and today most papers in the field of clinical orthodontics give at least a token acknowledgement to the lateral head radiograph. The specific references to Class II, Division 2 are, however, strikingly sparse. In most references to differences in morphology there is mention of the Class I type face, the Class II type face, and the Class III type face, there being no differentiation of the divisions of Class II.

A few investigators have made references to certain morphologic differences in the two divisions of this class. Baldridge[3] in 1941 made a study of the relationship of the upper first permanent molar to cranial landmarks. His work showed that the molar assumes the same definite relation to the face and cranium in Class I and Class II malocclusions. He pointed out that the base bone of the mandible in Class II, Division 2 cases is in the correct anteroposterior relation to the face and cranium, but it may be longer in its overall anteroposterior length. Continuing his study in 1950[4] he related the upper first permanent molar to Frankfort horizontal plane and again these angular measurements showed that there was no difference between Class I and Class II cases. In this study he made a linear measurement of the position of the maxillary first permanent molar in relation to point A. The vari-

*Read before the Edward H. Angle Society of Orthodontia, Washington, D.C., October, 1957.

ations found here were in the younger age groups and were thought to be a result of the mixed dentition. Adams[1] has pointed out that there is no difference in the absolute dimensions of the mandible in Class II malocclusions in relation to Class I malocclusions. Elman[7] showed that the lower first permanent molar bears the same definite relationship to the morphology of the mandible in both Class I and Class II malocclusions. In a study of the total facial pattern Renfroe[8] differentiated between Class I, Class II, Division 1, and Class II, Division 2. His conclusions were that there was no lack of development of the mandible in either division of Class II, and that Class II was characterized by a posterior position of the mandible. Renfroe's conclusions concerning the posterior position of the dental arch in Class II, Division 2 and its more forward chin point such as seen in Class I, were due to the fact that the Class II, Division 2 had a more square type face with a mandibular border that was more nearly horizontal and slightly longer than the Class I and the Class II, Division 1 mandible.

In 1954 Swann[9] presented another aspect of Class II, Division 2 in which he stated that the problem was one of developmental growth of the maxilla and the eruption of the maxillary teeth. He stated that this type of malocclusion was not primarily a skeletal dysplasia as is Class II, Division 1. His working hypothesis, based somewhat on the work of Elsasser and Wiley and also that of Howes, suggested that the upper second permanent molar developed ahead of tuberosity development and, in turn, caused a forward tipping of the maxillary buccal segments, which subsequently caused the abnormal arrangement of anterior teeth.

In the same year Blair[5] presented a detailed study on the morphology of Class I and Class II. He concluded that a high degree of variability of facial skeletal pattern can be seen within each class of malocclusion and that there were only minor differences between the mean skeletal patterns of Class I and Class II, Division 1 malocclusions. The mean skeletal pattern of Class II, Division 2, however, differed in a more acute gonial angle, a decreased effective length of the mandible, and a more forward position of the anterior outlines of both mandible and maxilla. His comments on the theory of "Compensatory Variation" give much food for thought.

Methods and Materials

In this study the primary criterion for case selection was the clinical diagnosis of Class II, Division 2 by a member of the Eastern Component of the Angle Society. This meant that it must conform to the classic description by Angle in the mind of the clinical orthodontist. The members of the Eastern Component selected such cases from their files and, where available, submitted lateral head radiographs. These radiographs were sorted, and only the prospective radiographs showing permanent dentition were used. The final group consisted of fifteen cases, five male and ten female. Tracings were made using acceptable standardized anatomic landmarks. Since these radiographs were obtained by various types of head holding devices, machine landmarks were avoided whenever possible. Again, because of the differences in mechanical devices some variation of head position would seem to be present. Accordingly, midsagittal reference points were used wherever possible. When bilateral structures were used, distances between images were halved. Since this was a clinical evaluation and not a compilation of statistical standards, measurements, while performed

with normal accuracy, were made only to the closest degree or millimeter.

Findings

Upon visual examination of these radiographs the subjective opinion developed that all of the cases were quite similar. The superposing of the tracings of headplates showed that certain variations existed. Initially, a composite tracing of the mandible using Broadbent's registration point for superposing showed that the general proportions of the mandible appeared to be similar. But the variation in gross size and special position made for a conglomeration of lines. Accordingly, the maximum and minimum variation both in anteroposterior position and inclination of the mandibular border are shown in Fig. 1. In an effort to ascertain the relative position of the maxilla and mandible in relation to cranium, the tracings were superimposed on the line NS with the points N coinciding. The variation of points A and B are shown in Fig. 2. Again, a similarity was seen but this similarity is influenced by gross size and spatial relationships of parts. Because considerable variation seemed to be evident from the visual examination of these composites, a line diagram was made from each tracing which would be sufficient to develop the measurements for four basic analyses. Figure 3 represents a typical diagram with the measurements of the four analyses which were used. To make the situation more graphic each case was recorded on the Vorhies-Adams polygon of the Downs' analysis. Again the variations of the individual cases seemed great enough to warrant making a composite polygon to show the maximum variations of these fifteen cases in comparison with the polygon of the Downs' normals. This is shown in Fig. 4. This composite polygon shows graphically certain variations which were expected. With one exception the variations were not particularly great. That exception, of course, is the relationship of the axial inclination of the upper incisor to the lower incisor. Since this was the most startling variation, this measurement was used as a base with which to compare other measurements in an effort to find some correlation that might be significant. Most comparisons showed no correlation, but some, while not showing any correlation, pointed out certain interesting variations.

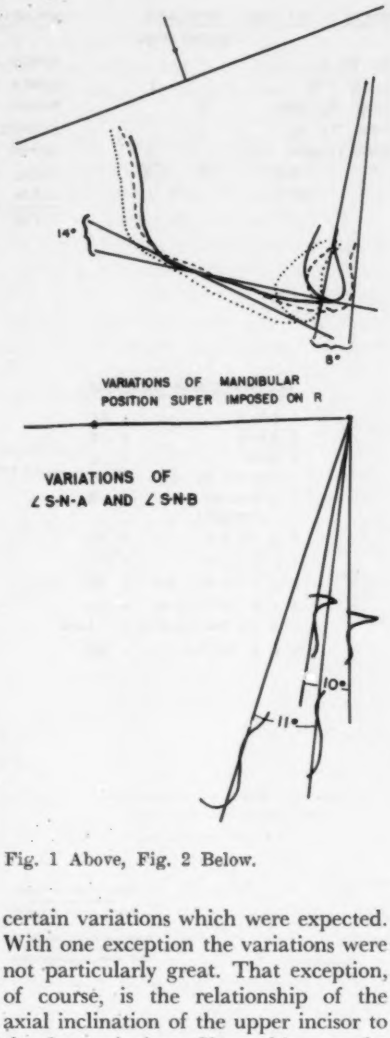


Fig. 1 Above, Fig. 2 Below.

WYLIE - ANT. POST DYSPLASIA	ORTHO	PROG
GF TO S		
S TO PTM		1
PTM TO ANS	6	
PTM TO $\underline{6}$	1	
MAND. LENGTH		3
TOT.	7	4
DIFF.	-3	

WYLIE-JOHNSON-VERT. DYSP.	
CONDYLAR ∠	=124
LOWER BORDER MAND	= 65
RAMUS HEIGHT	= 57
CONDYLE TO FH	= 0
UPPER FACE HEIGHT	= 55
TOTAL FACE HEIGHT	=121
$\frac{U.F.H.}{T.F.H.}$ x 100	=45.4

DOWNS ANALYSIS	
FAC. ∠	= 82
∠ CONVEX	= 8
AB TO FAC.PL.	= -14
MAND. PL.	= 30
Y AXIS	= 65
CANT. OF OCC.	= 13
∠ $\underline{1}$ TO $\overline{1}$	= 139
∠ $\overline{1}$ TO OCC.	= 22
∠ $\overline{1}$ TO MAND.	= +5
$\underline{1}$ TO APo(MM)	= 3MM

NORTHWESTERN ANALYSIS	
1. S-N-A	= 81
2. S-N-B	= 75
3. DIFF.	= 6
4. N-S TO Go-Gn	= 35
5. ∠ N-A-Po (CONVEX)	= 8
6. $\underline{1}$ TO N-S	= 91
7. ∠ $\underline{1}$ TO $\overline{1}$	= 139
8. ∠ $\overline{1}$ TO Go-Gn	= 95
9. ∠ $\overline{1}$ TO OCC. PL.	= 68
10. $\underline{1}$ TO FAC PL(MM)	= 5MM
11. ∠ $\underline{1}$ TO FH	= 95

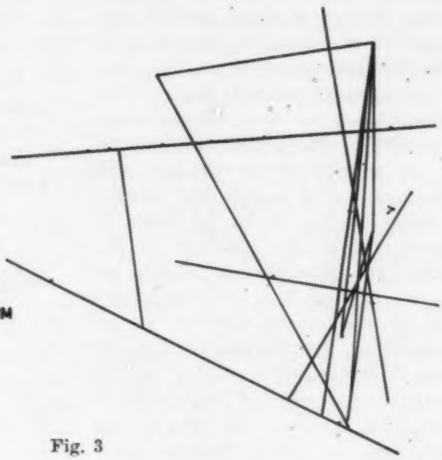


Fig. 3

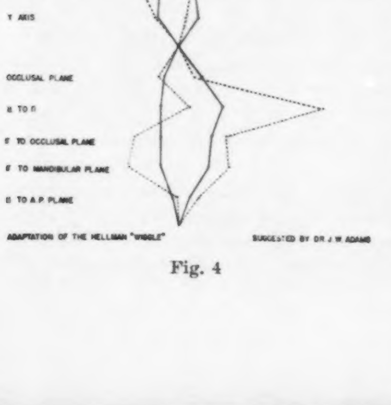


Fig. 4

Since the angular measurements of the incisors are in the anterior portion of the face, a scattergram was made of their relationships to NAP, the angle of convexity. This scattergram shows no correlation (Fig. 5), but it is significant that all but one of the cases showed a marked increase of the angle of convexity over the so-called average normal. The interincisor angle was then compared with the angle which the upper central incisor made to the line NS. This scattergram (Fig. 6) shows a reasonable correlation. Again, the angle which the upper incisor made to the line NS is considerably smaller than the average normal. Figure 7 shows a similar correlation between the inter-

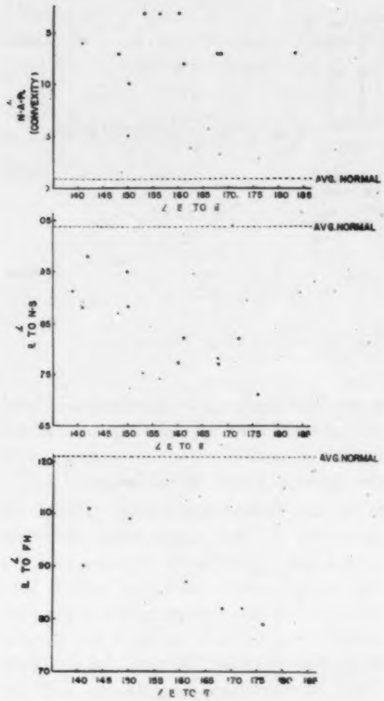


Fig. 5 Above, Fig. 6 Middle, Fig. 7 Below.

incisor angle and the angle of the upper central incisor to Frankfort horizontal plane. In this case the correlation would appear to be somewhat closer. Since these correlations occurred with a relationship between the upper incisor and cranial bases, a similar scattergram was made with the angular inclination of the lower incisor to the mandibular plane (Fig. 8). Again, we see a correlation of these two factors, six of the cases showing a more procumbent incisor angle than the average normal and nine cases being in a more lingual version.

Figure 9 shows the lack of correlation between the interincisor angle and the angular difference between the angles SNA and SNB. Although there is no correlation between these factors, it is again interesting to note that all of the cases showed a markedly greater angular difference between the points A and B than the average normal. Figure 10 shows the plotting of the interincisor angle against the mandibular plane as projected from the cranial base NS. While we again see no correlation, we see that six of the fifteen cases had a mandibular plane angle greater than that seen in the normal and the remainder were markedly less. The same interincisor angle was plotted against the gonial angle and is shown in Fig. 11. Only one case showed a gonial angle of greater size than the average normal. The others were more acute, although twelve cases were grouped within ten degrees. The percentage of upper face height is shown in Fig. 12. An interesting factor is shown here in that all but one case has a percentage

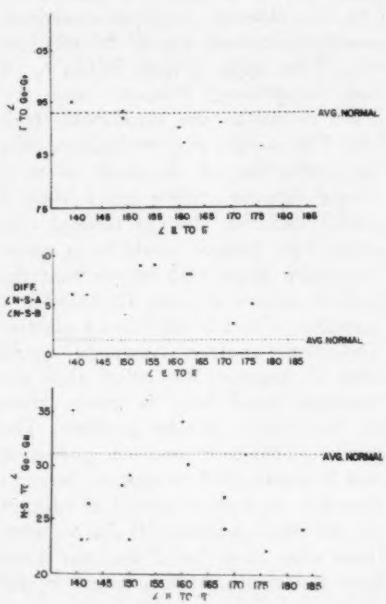
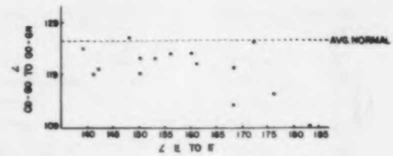


Fig. 8 Above, Fig. 9 Middle, Fig. 10 Below.

upper face height greater than the average normal. Conversely, this would mean that the lower portion of the face was markedly less.

Discussion

This presentation is intended to set forth certain factors, determined from clinical material, as one would utilize the various procedures and norms set up by research studies. The graphic portrayal of the variations shown on the Vorhies-Adams polygon indicates that there is a tendency for the overall group to vary somewhat from the normal pattern, and yet any one of the individual cases might well show a close similarity to the normal pattern. The indication would be that there is considerable variation of the Class II, Division 2 skeletal pattern. The most striking variation, of course, is the upright position of the incisor teeth. In using this as a means of comparing other variables the only place where a correlation existed was in the relationship of the upper central incisor to its basic supporting structure and the lower incisor to the mandibular base line. This would tend to indicate that the inclination of the teeth is of a coronal tipping variety rather than a spatial variation due to skeletal dysplasia. This thought would be in agreement with those who believe that the skeletal pattern of Class II, Division 2 is similar to that of the Class I pattern. The larger angle of convexity would tend to support the belief that the maxillary basal bone is either larger or in a more anterior position. The greater difference between points A and B would tend to support Swann's thoughts on a more mesial shifting of the maxillary dentition. It also supports those who have found that the basal bone in the mandible is longer in this division and the mandibular dentition situated more posteriorly over its basal



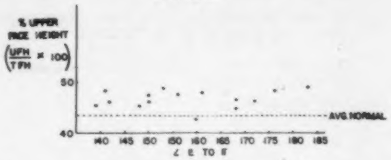


Fig. 11 Above, Fig. 12 Below.

bone. The flatter mandibular plane and the more acute gonial angle is in accordance with Renfroe's thinking as is the lack of lower facial height.

All of these cases were judged by members of this component as being true Class II, Division 2 cases and yet the morphologic variation which was found from the radiographic standpoint would tend to indicate that the clinical syndrome may be the result of different types of variables in different individuals producing the same end result. If this is true, then various avenues of thought may be formulated concerning the proper plan of treatment as it may apply to the individual case. The thought of considerable variation within the type as expressed by Blair would seem to be most acceptable here. Observation from the purely subjective clinical standpoint would tend to give some credence to the working hypothesis as set forth by Swann. The only new evidence set forth here would be the increase in lingual tipping of the anterior teeth. If this is accepted, then there must be some functional force causing this tipping. The subjective answer would accordingly be a matter of muscular balance and pressure. This though, of course, is not new. Fifty years ago the following quotation appeared in print, "In the harmonizing of

the anterior part of the upper arch with that of the lower through lip pressure the malarrangement of the incisors varies considerably, which, not infrequently, however, assumes one of two different and more or less constant types."[2]

Conclusions

1. Class II, Division 2 malocclusion is not a specific stereotyped clinical syndrome.
2. This situation may arise as the result of compensatory variation, eruptive disharmony, or muscular pressure. It is probably a result of the combination of all of these factors.
3. Clinical treatment plans and prognosis should be based upon the specific variations within the individual.

West Avenue at Cedar Street

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A Technique For Treatment With Cervical Gear*

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As one studies the results of his work during the conduct of a clinical practice, a generalized pattern of thinking develops relating diagnosis and treatment in his hands to the desired final result. This may be referred to as his philosophy of treatment.

Sometimes observation of the conclusions of a few cases will instill in one the urge to pursue a particular method and attempt to modify and refine it to achieve his desired result. Figure 1 shows just such a patient. She represented to me a type of dentofacial deformity in which I had been previously unable to elicit the necessary response with the then conventional techniques to produce a face and denture within a tolerance acceptable to me. She was treated in accord with the method outlined here and an acceptable dentofacial development was attained. Study of her case and others like it stimulated further efforts in this direction.

Since we are not working from a blueprint nor toward a universal standard, each of us strives for a certain facial balance in his treated cases which typifies beauty to him. To reach our particular goal we may use or modify any of a number of appliances and techniques. The faces shown in Figure 2 illustrate the results of this technique in a range satisfactory to this worker. This approach to treatment is based upon several premises:

1—It is well known that dentofacial changes are accomplished most readily during periods of general physical growth. Yet the problem which confronts the orthodontist is that the last great growth spurt in the human coincides roughly with the loss of the last deciduous teeth and eruption of many of the permanent teeth. Worse yet, to get the most from traditional techniques, he needs the fully erupted second molars for anchorage. All too often these complete their eruption long after the golden opportunity has passed. Hence the effort for maximum facial improvement is often deferred until teeth are present to make possible maximum dental improvement.

2—It is definitely easier to move one or two teeth at a time than to move all the teeth in one arch. Recognition of this is seen in the common practice

Fig. 1

*Read before the Edward H. Angle Society of Orthodontia, Washington, D.C., October, 1957.

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Fig. 2

of retracting cuspids into the extraction spaces prior to moving the other anterior teeth. Similarly, in second bicuspid extraction cases, the first bicuspids are usually moved distally alone and then the cuspids.

3—The placement of the orthodontic appliance sometimes aggravates the orthodontic problem. There is little doubt that the presence of the interproximal band material on twenty-eight teeth in some instances complicates a case in which a mild discrepancy exists. Yet control of the teeth frequently requires use of multiple band techniques.

4—Establishing proper interdigitation of the teeth is a paramount aim of orthodontic treatment and the first step

in this direction is to correct the relationship of the permanent molars.

With these points in mind, the use of the double bow and cervical gear described by Kloehn[1,2] becomes an important part of treatment in a sequential philosophy.

A cursory review of the literature will reveal that men have appreciated the value of extraoral anchorage for many years. It will also be noted that the methods of applying this force have a great deal in common. In fact, the main variations are in the direction of force and the precise means of transferring this force to the teeth. All of the methods involve use of a pliable material which may be adapted to the shape of the patient's head and/or neck and used as a source of anchorage; use of some elastic material to provide the force; and the use of a bow or bows to transmit this force to the teeth through archwires or bands.

The question of the direction in which this force is applied has obviously been a matter of interest for many years as is evidenced by the tremendous number of designs which have been suggested. It is still being debated today. This paper recognizes the validity of the problem and is presented to describe the possibilities of force application in one simple method.

While the time to institute orthodontic treatment is a widely discussed topic, it is commonly agreed that treatment of dentofacial anomalies is most favorable during periods of general physical growth. In my practice children are kept under observation and their treatment is instituted in conformity with this view whenever practicable. As the time approaches when the first bicuspids and cuspids are well developed in their crypts, maxillary first molars are banded carrying .045 buccal tubes and the familiar double bow and cervical gear are placed as shown in Figure 3.

Fig. 3

The entire approach to the problem is based upon the concept of sectional therapy. The cases amenable to this approach may or may not have spacing and severe labial inclination of the incisors. Nevertheless, in most cases the molar relationship is attacked first. Stops cut from buccal tubing are soldered to the archwire advancing the entire bow three to four mm. from the anterior teeth. The outer bow is given a severe downward bend and the inner arch is given a compensating upward bend. The resulting force exerts severe tipping action on the maxillary first molars which, when coupled with the distal pull of the cervical gear, will open a sizable space between these teeth and the deciduous second molars as seen in Figure 4.

This point provides a fair estimate of progress for, in the more favorable cases, these spaces appear and open rapidly within 4 to 8 weeks. Their absence usually means the gear is simply not being worn enough. As the first molars tip and move distally, the stops are also moved distally and the outer bows are given more downward tipping. Meanwhile the inner arch receives more compensating upward bending.

When the molars are moved distally enough, the stops are moved mesially on the inner bow and all pressure is applied to the anterior teeth. The outer

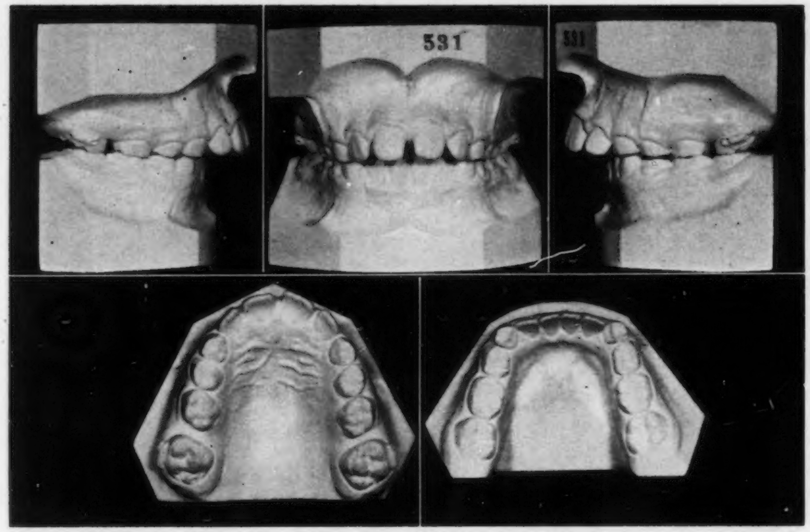

Fig. 4

bow is shaped by bending the arms severely upward. This necessitates a compensating downward bend on the inner arch. During this phase the patient must be seen frequently for, as the molar roots move distally and the teeth become vertical, the inner arch tends to ride gingivally up the incisor

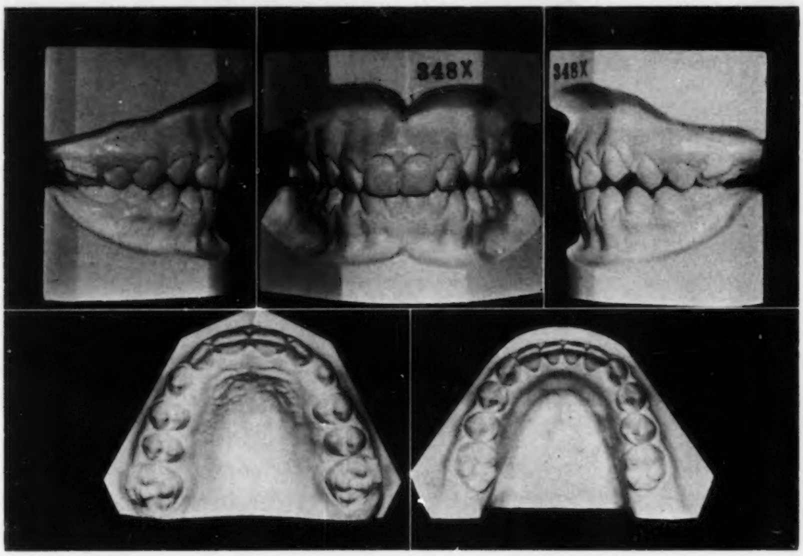

Fig. 5

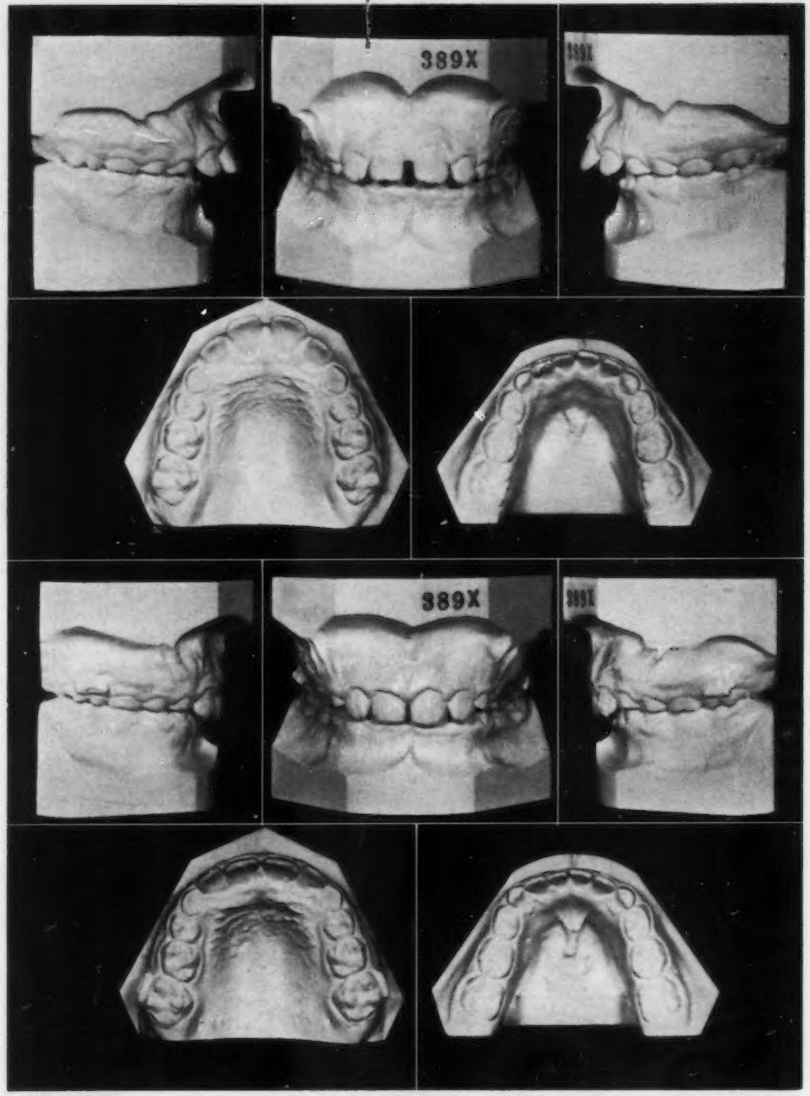

Fig. 6 Above, Fig. 7 Below.

teeth. Attention to this detail pays dividends for pressure is maintained on the anterior teeth and they now progress distally until the lower anteriors strike their lingual surfaces.

In many instances these two steps complete this phase of treatment, in which case, a bite plate is placed to open the bite slightly. The stops are moved distally to exert mild pressure

on the molars and the gear worn until the permanent teeth erupt fully and interdigitate or when it is evident that the case is going to settle in properly. Then the headgear may be discarded and only the bite plate worn until the dentition is completed as in Figure 5.

In other, more severe cases at this stage, when the bite plate is placed, it is ground away to free the molars and the entire procedure is then repeated: (1) tipping and distal movement of the molars and development of interdental spaces while increasing vertical dimensions with the bite plate; (2) reversing the tipping action on the molars and transferring the distal pressure to the anterior segment only without the interference of the bite plate.

When the case presents initially with extreme protrusion and spacing of the incisors as in Figure 6, the appliance is first placed with no stops and the force directed distally upon the anterior teeth. The arch is allowed to slide freely through the buccal tubes and the anterior teeth are driven distally closing most of the anterior spacing as in Figure 7. A bite plate is placed to retain them, the plate ground free from the molars and the molar relationship attacked as mentioned earlier.

It is only fair to state that it is frequently difficult to get perfect interdigitation of the cuspids on one side as seen in Figure 8; you may deem this a flaw in the method. However, its many advantages outweigh this slight disadvantage. A positioner may be used for final detailing to overcome this deficiency in the method.

Having seen the successful results of this mechanism as advocated by Kloehn[1 2] it has seemed logical that the same application of force could be equally advantageous as an adjunct to treatment in other types of malocclusions where distal movement is desired. Several other general patterns of malocclusions respond well to this method when used in conjunction with conventional techniques including multiple banding, even when treatment is instituted at considerably later develop-

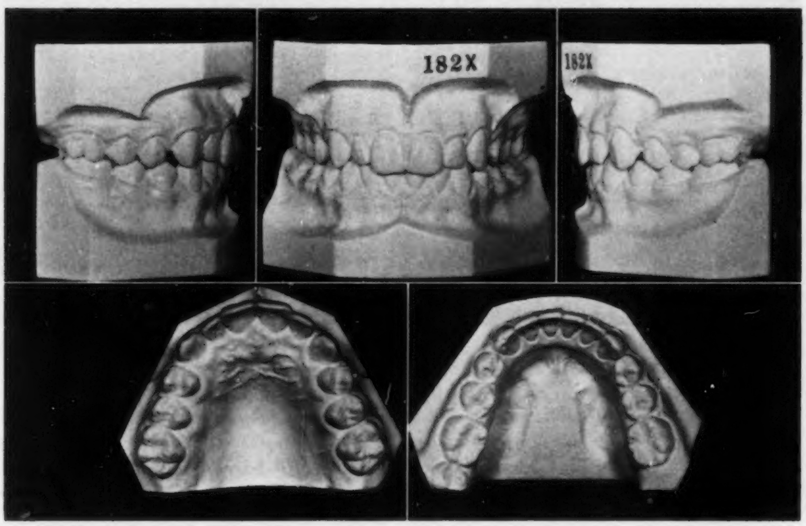

Fig. 8

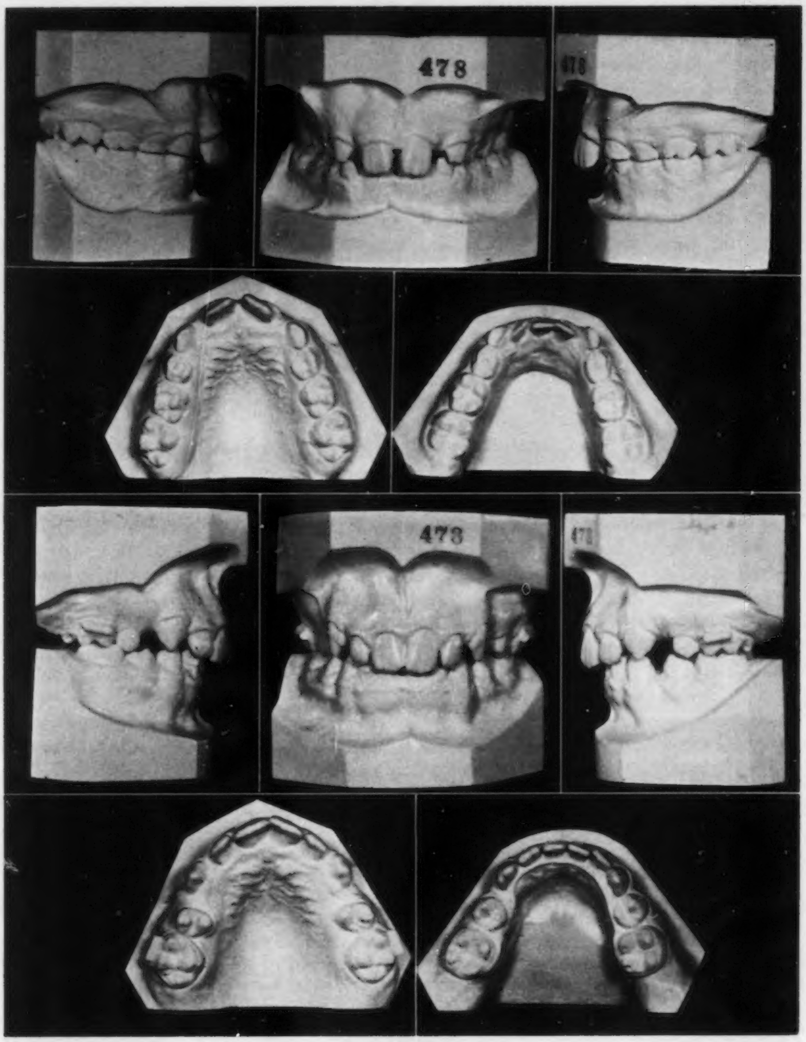

Fig. 9 Above, Fig. 10 Below.

mental age levels.

The procedures involving early removal of dental units in selected cases offer an excellent opportunity for the sectional movement of teeth. (Figure 9) Following the extractions of the bicuspids a lower lingual arch is placed and the Kloehn gear applied to the maxillary units. The molar relationship is first corrected; then the bow redirected to move the anterior teeth distally. During this time the cuspids usually erupt and drift into desirable position. When the second bicuspids

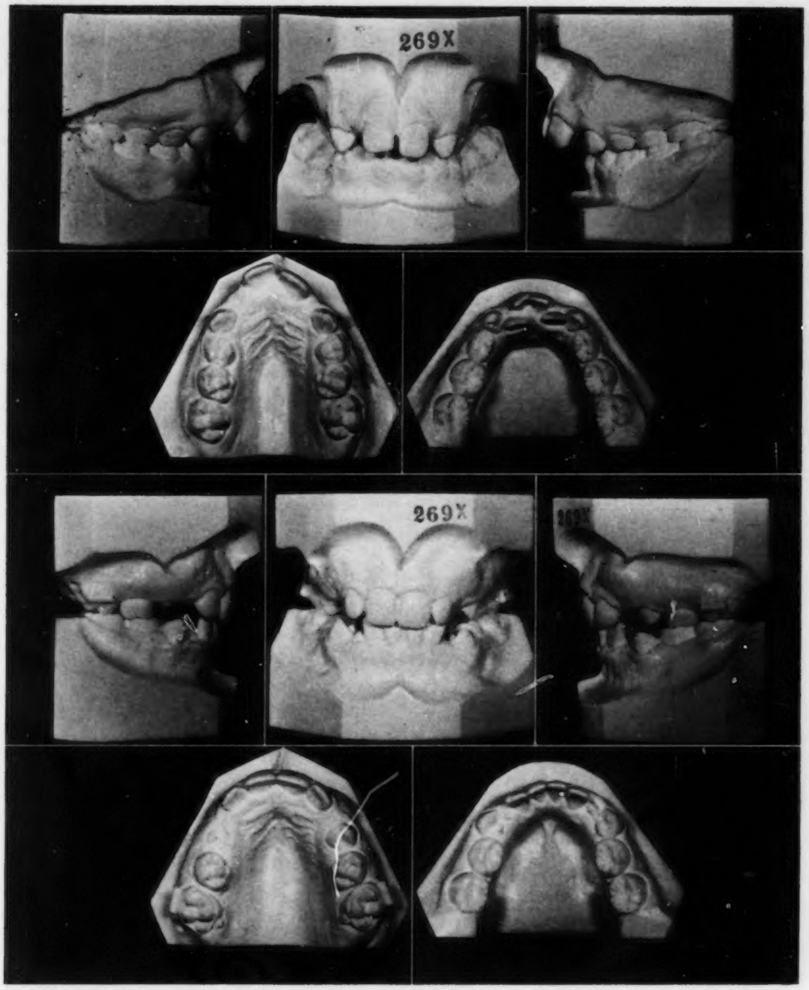

Fig. 11

erupt, the case is banded completely and the teeth moved into correct detailed positions (Fig. 10). In the illustrations for Figures 11 and 12 may be seen still another type of discrepancy case which will frequently respond to this type of early intervention. The constricted maxilla is first expanded to free the bilateral crossbites and the cervical gear as described placed at once. The casts and photos of the patient demonstrate a very clear and steady progress toward the desired normal. This technique certainly does not eliminate the obligation to band the case, complete space closure in the proper fashion, open the bite and place individual teeth into carefully detailed positions. How-

Fig. 12

ever, it does reduce materially the period of time that bands are on teeth other than the four first molars while, at the same time, reducing the malocclusion to simple proportions.

In maxillary protrusions where extractions are indicated and a Class I molar relationship exists, following extractions the lower arch is banded to include first and second molars, second bicuspids and cuspids, and leveled off. At the same time, the upper arch is fitted with the Kloehn gear which is adjusted to place straight distal pressure on the anterior teeth. The lower arch is worked up to a rectangular arch with mild tip-backs and the cuspids retracted with cuspid to cuspid coils, DR 11's or sectionals with Bull loops. As this occurs, the upper anterior teeth are kept retracted against the lower anteriors and much of the extraction space in the upper arch is closed. When the lower cuspids are moved well back, the upper teeth are banded, and rectangular .022 x .028 tubes added to the upper first molar bands. Distal pressure is maintained on the molars by means of stops soldered to the inner bows while leveling off and during retraction of the cuspids. Retraction of anterior teeth in both arches is accomplished with rectangular wires formed with Bull-type closing loops. In the maxillary arch lingual root torque in the region of the incisors is used. Just distal to the central incisors, hooks are soldered and a high pull headgear maintains distal pressure. A similar rectangular arch is placed in the mandibular brackets but with the incisor section rounded to eliminate root torque. Finishing arches are then placed for final detailing of the teeth. Figure 13 shows an example of this type in which all major movement of teeth in the maxilla was accomplished solely with the cervical gear. Even space closure having been completed, bands were only placed on the maxillary teeth for the final three months of treatment to affect detailed positioning of the teeth.

Maxillary protrusions with a Class II molar relationship and deficient basal bone structure necessitating removal of teeth are started in the same manner in the mandibular arch. In the maxilla, the upper first molars are again banded bearing .045 buccal tubes and the Kloehn-type cervical gear placed with soldered tube sections on the inner arch for stops. The stops maintain the inner arch in a position free from the incisors. Rather severe tipping force is applied in conjunction with distal traction and is maintained until a Class I molar relationship is achieved. If undesirable tipping should occur, it may be corrected by reversing the direction of the bends in the outer and inner bows as mentioned earlier. We all know that in spite of our best efforts that space closure in the mandibular arch invariably results in some mesial movement of the buccal segments; this certainly contributes to correcting the molar relationship.

When the molar interdigitation is

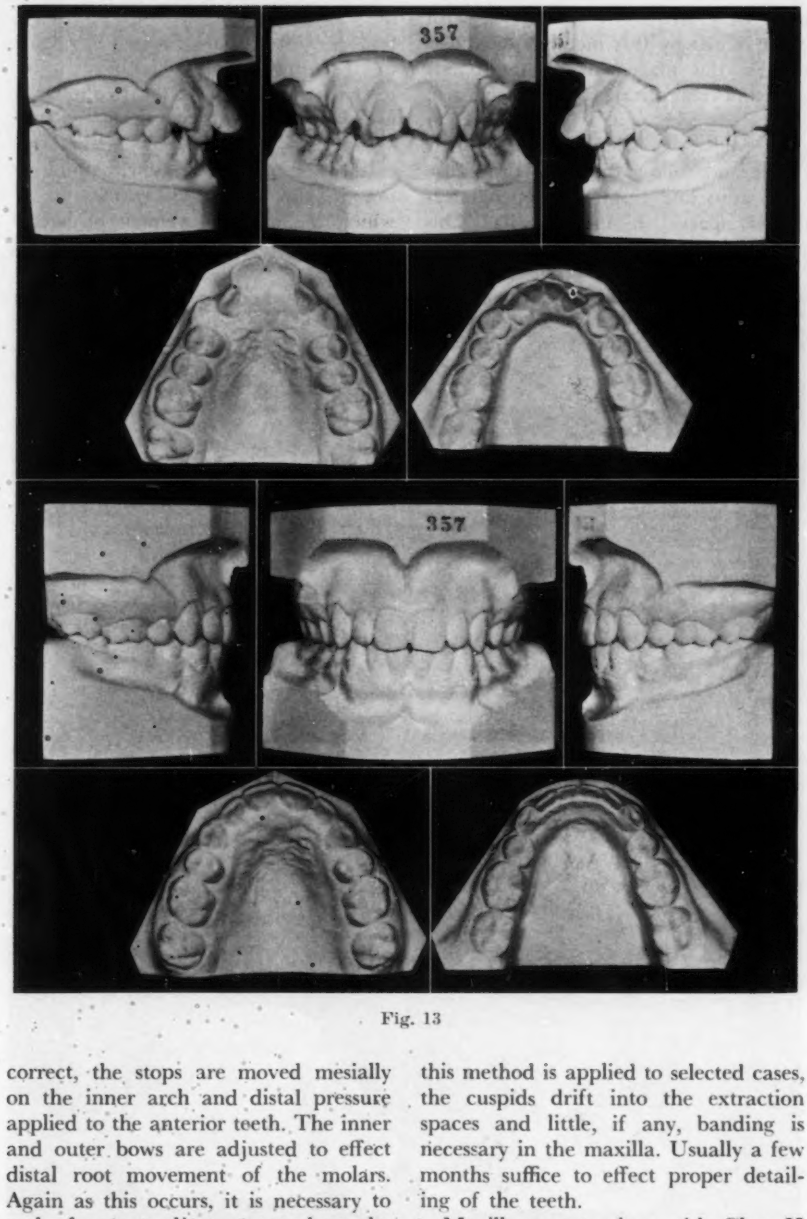

Fig. 13

correct, the stops are moved mesially on the inner arch and distal pressure applied to the anterior teeth. The inner and outer bows are adjusted to effect distal root movement of the molars. Again as this occurs, it is necessary to make frequent adjustments to keep the arch riding on the anterior teeth. When this method is applied to selected cases, the cuspids drift into the extraction spaces and little, if any, banding is necessary in the maxilla. Usually a few months suffice to effect proper detailing of the teeth.

Maxillary protrusions with Class II molar relationships and sufficient basal

bone may frequently be started with good results by this method. As stated earlier, the placement of the bands sometimes complicates the malocclusion. Hence, on occasion, it is desirable to place only the maxillary first molar bands and follow the basic procedure with stops and tipping to open interdental spaces in the maxilla. This method will frequently almost correct the molar relationship. In any case, a few months of effort directed at setting up a better molar relationship prior to placing a full orthodontic appliance usually pays big dividends.

One may also use this method for cases which present treatment problems not readily solved by extractions in which the distal movement of buccal segments is the only alternate solution.

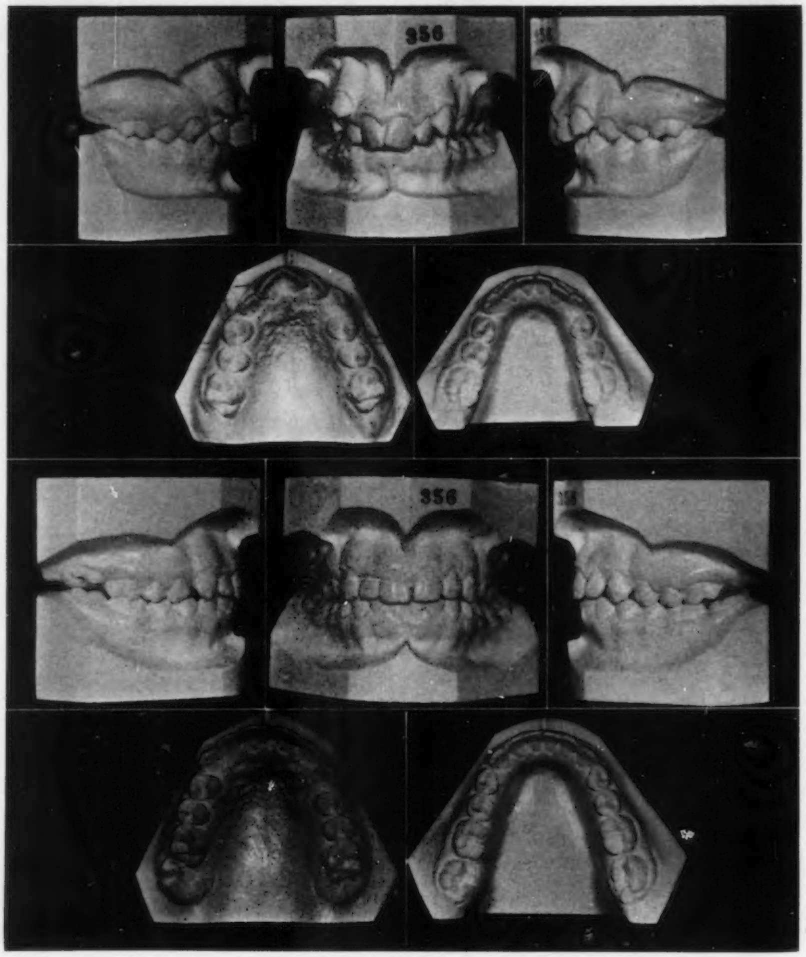

Fig. 14

Fig. 15

Figures 14 and 15 illustrate a case involving elements of facial balance, angulation of teeth and depth of bite which contraindicated removal of teeth. She was accepted for treatment with the understanding that teeth would be removed if the necessary distal movement was not obtained. Only the cervical gear was placed and worn for six months which corrected the molar relationship. Then the rectangular tubes were added and a full edgewise appliance placed on the upper arch while the cervical gear continued pressure on the molars. The lower arch was banded nine months later with full edgewise appliance and final interdigitation accomplished in six months.

In summary, a method has been presented whereby one may institute treatment at desirable age levels when it is possible to effect maximum dentofacial improvement without depending upon eruption of all the teeth or which may be used at later developmental levels to greatly conserve anchorage and assist in the sectional movement of dental units in a distal direction.

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Class II, Division 2 Malocclusion*

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In discussing Class II, Division 2 malocclusion the essayist would emphasize the fact that there is a very small percentage of cases found in this category. Probably this is the reason why comparatively little literature is in print dealing with this particular group of cases. These two facts prompted the Eastern Component to present this symposium. Owing to the fact that this was not a research project but purely a clinical study of methods of treatment and results obtained, we believed the material available was sufficient to serve our purpose.

For a historical review of the subject one quite naturally turned to Dr. Angle's text for the definition of this form of malocclusion. Therein is found the following words. "Division 2 (of Class II) is characterized specifically also by distal occlusion of the teeth in both lateral halves of the lower dental arch, indicated by the mesio-distal relations of the first permanent molars, but with retrusion instead of protrusion of the upper incisors."

It is interesting to note that in this definition Dr. Angle does not mention the distal relationship of the mandible as entering into the deformity. However, in his preliminary remarks on classification, page 35, seventh edition, he writes: "These classes are based on the mesio-distal relations of the teeth, dental arches and jaws, which depend primarily upon the positions mesio-distally assumed by the first permanent molars on their erupting and locking. Hence in diagnosing cases of malocclusion we must consider, first, the mesio-distal relations of the jaws and dental arches, as indicated by the relation of the lower molars with the upper molars — the keys to occlusion; and second, the positions of the individual teeth, carefully noting their relations to the line of occlusion."

Turning to the chapter on Treatment of Class II, Division 2, we do find Dr. Angle placing emphasis on the facial deformity caused by the distal position of the mandible and the lack of vertical growth below the nose.

On page 514 he states: "the result of distal occlusion and recession of the jaw and chin greatly mars the facial lines."

Consequently it seems reasonable to deduct that Dr. Angle was considering the relationship of the mandible to facial structures, as well as occlusion of the teeth, in classifying a Class II case.

He considered Division 2 easier to treat than Division 1 and describes his treatment as follows: "Briefly it consists in moving distally all the molars, premolars and canines of the upper arch about one-half the width of a premolar tooth, with a simultaneous and equal mesial movement of the lower arch, thus establishing the normal relations and functions of all their inclined planes and the best possible balance of the facial lines."

The excessive closed bite which is so evident in Class II, Division 2 cases is called to the attention of the student by Dr. Angle in only one case report. He attributed this to the fact that the "molars have failed to erupt to their normal length, allowing the lower in-

*Read before the Edward H. Angle Society of Orthodontia, Washington, D. C., October, 1957.

cisors to come in contact with the vault of the arch, while the cutting edges of the upper incisors pass beyond the gingival margins of the lower. Of course, this abnormal telescoping of the incisors is due in no small degree to the tipping downward and inward of the upper incisors from their normal angle, and the tipping lingually of the lower incisors, and although such a condition is more or less present in all cases belonging to this division, yet it is here present to an unusual degree, the principal reason being that the molars have not fully erupted" (Fig. 1).

Fig. 1 Illustration of a Class II, Division 2 case taken from Dr. Angle's Seventh Edition, page 529.

In Calvin Case's *Dental Orthopedia,* on page 287, is an illustration in which the plaster facial reproduction clearly indicates a Class II, Division 2 malocclusion. Dr. Case terms it "a general bi-maxillary infra-occlusion." He treated this by a universal elevation of all of the buccal teeth, opening the bite primarily with crowns on the molar teeth to separate the premolars in order that they could be elevated with elastics, and then removing the crowns from the molars and elevating these in turn. Whether the result was permanently stabilized is not mentioned.

Milo Hellman, in a paper on Class II cases, reports his deductions from measurements on skulls exhibiting Class II relationships of the teeth. He states, quoting from Gordon C. Swann's paper, that in Class II, Division 2 cases "the maxillary alveolar process appears to have drifted anteriorly; the teeth therein consequently were in mesial relation to those of the mandible."

Earle W. Renfroe, in the *Angle Orthodontist,* Vol. 18, pages 12-15, reports a *Cephalometric Study of Facial Patterns Associated with Class I, Class II, Division 1, and Class II, Division 2 Malocclusions.* Transcribed from his deductions are the following conclusions:

1. That Class II malocclusions of both Division 1 and Division 2 types are not characterized by any lack of development of the mandible.

2. That the maxillary first permanent molar, instead of being anterior to its normal position in Class II malocclusion, has a tendency to lie more posteriorly, as previously pointed out by Hellman, Oppenheim and Baldridge.

3. That Class II cases are characterized by a posterior position of the mandible as claimed by Angle.

4. That the angle of the mandible is larger in Class I than in Class II cases of either division.

5. That while the dental arch is posterior in Class II, Division 2, the chin point is almost as far forward as in Class I. This arises through the fact that the Class II, Division 2 case is a more square type with a mandibular border that is more nearly horizontal.

In 1933, the Eastern Component presented a paper before this Society entitled *"A Clinical Study of Cases of Malocclusion in Class II, Division 2."* In that report there are certain paragraphs which the writer believes are worth repeating. Attention in the report was focused largely upon the mandible. I quote the following:

"Anteroposteriorly, the mandibular denture appears somewhat 'stubby', owing to the lingual position of the incisor teeth, which is quite characteristic. There is seldom any curve of

Fig. 2 The classic form of Class II, Division 2 characterized by a distinct reduction of vertical growth in the oral area of the face and distal relationship of the mandible to the cranium.

Spee. The molars and deciduous molars are arranged on a level in the horizontal plane with no tendency of the first molars toward mesial tipping. The incisors are on a plane that is considerably and abruptly occlusally located to that on which the molars are arranged."

"The vertical growth of the mandible in the molar and premolar regions is decidedly lacking" (Fig. 2).

"The mandibular denture is often more distally placed, in relation to the maxillary denture, than in Class II, Division 1. The profile photographs, however, seldom show any greater degree of disharmony in the facial lines than in Division 1" (Fig. 3).

The reason for this is given as hypertrophy of the mentales muscles which cover up the deformity and also the excessive closure of the mandible due to the reduced vertical growth which throws the chin farther forward.

Mention is also made of the possibility of forward shifting of the buccal segments of the maxillary denture as indicated by the axial perversion of the lateral incisors combined with their

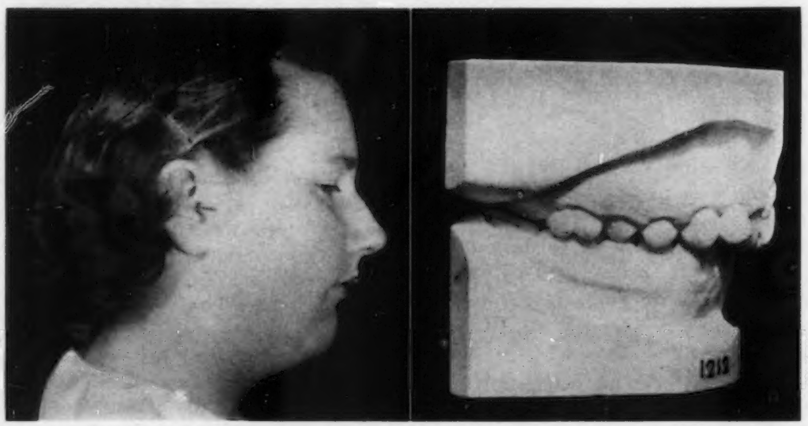

Fig. 3 Class II, Division 2 in the permanent denture. Note the distal relationship of the mandible to the cranium.

Fig. 4 A Class I case with occlusal tooth relationship simulating a Class II, Division 2 case.

overlapping of the central incisors. This, I believe, is an important observation.

In reviewing all of this literature one conclusion is quite in evidence. Some of the writers have classified their cases by tooth occlusion only, while others have classified them by mandibular positioning. That brings up the important question, "What is Class II malocclusion?"

Dr. Angle's text apparently does not make this clear enough to solve the question in the minds of many. Hence there probably will continue to be arguments as long as this classification is used. Personally, it seems logical, now that we know that the maxillary first molars are not always stationary guides, to take the bony foundations of the dentures as the more reliable indicators. We have a basis for this in Dr. Angle's statement previously quoted and again brought to your attention, i.e., "Hence in diagnosing cases of malocclusion we must consider *first* the mesio-distal relations of the jaws and dental arches."

Many orthodontists pay no attention to the position of the mandible in relation to the cranium in classifying Class II, Division 1 cases. They consider only cuspal relationships and hence we find many case reports in which Class I cases, with Class II relationship of the buccal teeth, designated as Class II cases. The same may be said of Class I cases with Class II, Division 2 cuspal adjustments. No doubt there are borderline cases in both of these divisions but the true Class II case presents a mandible in distal relationship to facial and cranial anatomy (Fig. 4).

In discussing the etiology of Class II, Division 2 the writer has only clinical deductions to offer. Heredity does enter into the problem, I thoroughly believe. Faulty growth patterns of facial and cranial structures are in evidence by the lack of vertical growth below the nasal area and by the distal positioning of the mandible. Muscular perversion, in the form of pressure against the maxillary central incisors, combined with excessive closure of the bite are mechanical factors to consider in the posterior positioning of the mandible.

In considering the prognosis associated with the treatment of Class II, Division 2 cases, there is one important factor that must be considered. I refer to the absence of vertical growth in the area of the face below the nasal passages (Fig. 5).

Clinical experience has demonstrated that success in stabilizing the corrected overbite present in these cases varies with the degree of vertical growth that

Fig. 5 Left, A Class II, Division 2 case with very good vertical growth in the oral area with a favorable prognosis for permanent stability of the corrected overbite.

Right, A Class II, Division 2 case with lack of vertical growth in the oral area and hence, a poor prognosis for permanent stability of the corrected overbite.

is present in the individual case under consideration. It would seem that muscular balance is a dictating factor in this situation. In other words, if there is marked evidence of lack of vertical growth in the facial area below the nasal passages, it is possible to correct the overbite in treatment; yet, subsequent to the removal of mechanical retention, a collapse invariably occurs.

This would indicate that muscle tension dictated this collapse. The corrected tooth positions remain undisturbed. On the other hand, if there is reasonably good vertical growth in the oral area, and in some cases of Class II, Division 2 there is, the corrected overbite obtained in treatment, by depressing the anterior teeth in both dentures, will remain well stabilized.

Therefore in rendering a prognosis in these cases, it is essential that the vertical height in the oral area be carefully observed and deductions influenced by this factor.

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A Study Of Pont's, Howes', Rees', Neff's And Bolton's Analyses On Class I Adult Dentitions*

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Since the beginning of modern orthodontics, the profession has continually tried to predict the success or failure of orthodontic treatment. While it must not be supposed that variations from normal occlusion can be measured accurately and that orthodontic diagnosis can be based upon mathematical calculation, nevertheless, the ability to predetermine arch size, within limits, is a useful diagnostic aid. Many methods of analyses have been formulated, based primarily upon successfully treated cases. This study is designed to test five prescribed model analyses of normal occlusions, Pont's, Howes', Rees', Neff's, and Bolton's and to note their validity.

Review of Literature

The validity of model analysis has been questioned by other men. In 1957 Martinek[9] presented an interesting paper comparing the analyses of Howes, Rees, Kesling[8], and Strayer[17] on five treated cases. They agreed in two of the five cases and varied in the others, pointing out their lack of agreement. These analyses were all based primarily on a relationship between tooth material and supporting bone; therefore, a review of these methods may reveal why the discrepancies occurred.

Howes developed his case analysis on the premise that, in normal dentitions, the width of the maxilla in the first premolar area must be at least 43 per cent of its tooth material. The tooth material referred to was the combined mesial distal measurements of all teeth in the arch from the right first permanent molar to the left first permanent molar inclusive, which he termed maxillary tooth material or M.T.M. The arch width in the first premolar region was taken just inside the summits of the buccal cusps of the first premolars. He felt that in order for an arch to maintain itself within this 43 per cent "normal" range, the width of the apical basal bone from canine fossa to canine fossa had to be 44 per cent of the M.T.M.

The canine fossa lies just above the first bicuspids and distal to the canine eminence. Maxillary apical base bone is that area which forms the junction between the body of the maxilla and the alveolar process, and lies at the level of the apices of the teeth. The canine fossa (C.F.) measurements were taken in the canine fossa just above the first bicuspids (Figure 1).

His study was started on fourteen normal dentitions. In two hundred subsequent cases, measured directly in the

Fig. 1 Howes' method for measuring canine fossa width.

*Thesis presented in partial fulfillment of the requirements for the degree of Master of Science, Ohio State University, 1958.

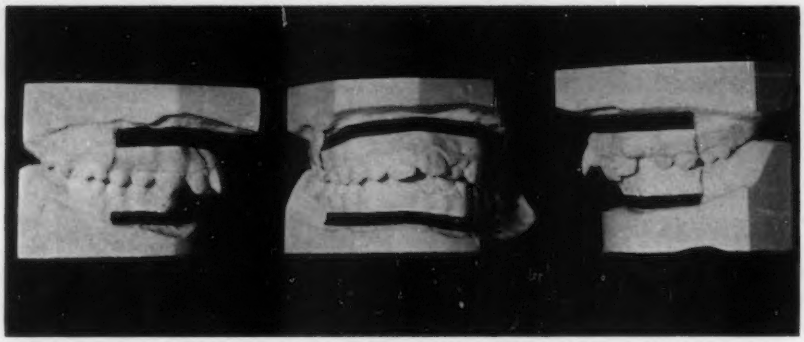

Fig. 2 Rees' method for measuring apical base.

mouth, he found that the C.F. measurement was never smaller than arch width at the first bicuspids. Thus, he interpreted a canine fossa measurement greater than that of the first bicuspid measurement as being the amount of expansion possible, and felt that no expansion could be expected to hold if it exceeded the canine fossa measurement. He also observed that distal movement of first bicuspids would increase the C.F. measurement.

On one hundred and twenty-five cases which he treated, Howes formulated his groups and made these conclusions:

1. If the ratio of canine fossa to the combined width of the maxillary first molars, premolars, canines, and incisors is 44 per cent, it may be assumed that the apical base is adequate.

2. If the ratio between C.F. and M.T.M. is between 37 per cent and 44 per cent, the adequacy of basal bone is questionable. In such cases, Howes suggests that it may be wise not to treat at all or to accept residual irregularity of the lower anterior teeth following treatment.

3. Extractions in treatment are definitely indicated if C.F. to M.T.M. is 37 per cent or less.

Rees developed a method for assessing the relationships that existed among maxillary apical base, mandibular apical base, maxillary tooth material, and mandibular tooth material. In this method tape was laid on an orthodontic cast in the zone of the apical base, from the mesial of each first molar to the other in its arch. The tape was firmly applied to the cast after all tissue attachments or artifacts were removed.

It was trimmed to represent the mesial of the first molar by placing a ruler against the side of the cast at right angles to the occlusal surface and cutting along that line. To ensure placing the tape over basal bone in the anterior region, it was placed 8 to 10 mm. apically from the gingival margin at the midline (Figure 2). The tape was then removed and its measurement in millimeters represented apical base. The tooth material, as in Howes, was the combined mesial distal measurements of all the teeth in the arch, but did not include the molars.

Rees measured twenty normal cases in which the teeth appeared in good relationship to basal bone, with no rotations, crowding, or spacing present. These measurements showed that upper apical base exceeds tooth mass by a mean of 3.2 mm., lower base exceeds lower teeth by a mean of 4.47 mm., the upper base exceeds the lower base by a mean of 6.34 mm., and upper

teeth exceed lower teeth by a mean of 7.57 mm.

Rees formulated the following chart to be used for quick analysis on any type of malocclusion. The quantities were reduced to the nearest .5 mm. U.B. represents upper apical base; U.T. represents upper tooth material; L.B. represents lower apical base; and L.T. represents lower tooth material.

	Mean	*Minimum*	*Maximum*
U.B. — U.T. =	3.5	1.5	5.0
L.B. — L.T. =	4.5	2.0	7.0
U.B. — L.B. =	6.5	3.0	9.5
U.T. — L.T. =	7.5	5.0	10.0

By comparing the table of average normals with the measurements taken on any set of casts, a determination with reasonable accuracy of the following diagnostic facts can be made:

1. If the relationship of the apical base to the tooth material of each arch is beyond the range, a discrepancy exists. This should be corrected to within normal limits by extraction, or whatever orthodontic procedures the operator feels is best. In borderline cases, internal and external muscular forces, facial esthetics, and other factors must be taken into consideration. A disparity of 7 mm. less than minimum when comparing tooth material to apical base is enough to warrant extraction of dental units (Martinek).

2. If the relation of maxillary base to mandibular base is beyond the range, a discrepancy exists between the opposing arches. Reduction of the teeth and the base may be necessary in one arch or, if this is not indicated, an expansion of the other arch is the only alternative.

3. If the relation of tooth size in maxillary to mandibular arches showed discrepancies beyond the normal range, spacing or crowding are unavoidable in the finished case unless the tooth mass is equalized by reducing it in one arch or increasing it by judicious placement of crowns or inlays in the other (Rees).

The philosophy underlying Rees' approach is that of Nance[10] which follows: Growth of the apical basal bone of both jaws subsequent to the eruption of the first permanent molar is confined to the distal portions to be occupied by the second and third molars. Vertical dimension increases in the alveolar process until full eruption of the teeth. Apical basal bone from first molar to first molar does not appear to change subsequent to the eruption of these teeth, except to decrease the equivalent of the amount of forward migration during transition from mixed to permanent dentition.

Kesling's method of analysis is the so-called "diagnostic setup." The teeth are sawed from the casts with a fine blade to be repositioned in order to determine the need of reducing tooth material.

On a roentgenographic cephalogram, the Frankfort plane and the position of the apex of the mandibular incisor are located. A line is then drawn from the incisor apex to the Frankfort plane, forming with it an angle of 65 degrees. The exact inclination of the mandibular incisor is then drawn and a measurement is taken from the incisal edge to the line drawn at 65 degrees to the Frankfort plane. This measurement, then, is the guide which determines the amount the lower incisor must be tipped. By waxing the remaining teeth to the mandibular cast, the adequacy of basal bone is determined. The maxillary teeth are then sawed from the cast and set up to occlude with the lower teeth. Kesling does not resort to removal of teeth if he can compensate inclinations of the mandibular incisors to within three degrees of 65. He encourages one to range slightly toward a 70-degree angle rather than a 60-degree angle similar to the philosophy

of Tweed[18], whose extraction deadline is 62 degrees. Kesling points out that Class II treatment usually increases the final angulation by about five degrees, which should be considered in the original calculations (Martinek).

Strayer's method of analysis is a visual means of judging whether the apical base is of sufficient dimension to accommodate all the teeth. He makes a drawing on plexiglass, reproducing the apical base, and marks the widths of the teeth on it in a manner similar to a Bonwill-Hawley diagram. This drawing is co-ordinated with the model by using a measurement from the apical base of the centrals to the distal of the model, which determines the depth of the drawing. Thus, when the drawing is placed over the cast so that the posterior surface aligns with the distal edge of the drawing, the relationship of apical base and teeth is readily seen.

From this review we note that the conclusions formulated by Howes and Rees were derived from a very limited number of normal occlusions and that their analyses were based essentially on clinical cases. Strayer does not state his material, and Kesling uses Tweed's statistics in his determinations. The different samples both in quality and quantity utilized in these analyses may explain the discrepancy in the results reported by Martinek.

Many other analyses have been proposed. In 1909 Pont presented to the profession a system whereby the mere measurement of the four maxillary incisors automatically established the widths of the arches in the premolar and molar regions. He showed that, by using his method, the final result was no different from that of Hawley[5] for the predetermination of arch width.

His reasons for choosing the four maxillary incisors only were to simplify the method for arch predetermination and to permit the use of the principles of arch predetermination before the eruption of the canine tooth (Hemley[6]).

Pont stated, "I must warn you that my research has been made exclusively on the jaws of the people of the French race and I would be much pleased if, at a later date, others of my colleagues could verify the correctness of this on other races." In translations Pont's material has not been adequately described except to say that a complete normal dental arch or a large number of arches were used in calculating the dimensions. The greatest widths of the incisors were measured with calipers, recorded on a line, and their sums then recorded in millimeters. The distance between upper right first bicuspid and upper left first bicuspid, and between upper right first molar and upper left first molar were similarly recorded (Simon[16]).

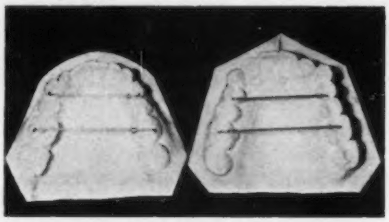

Fig. 3 Location of points used by Pont to determine arch width.

The measuring points were the distal end of the occlusal grooves of the first premolars and the mesial pits on the occlusal surface of the maxillary first molars (Figure 3). The points used on the mandibular teeth were the distobuccal occlusal point angles on the first premolars and the highest point on the middle cusp of the buccal cusps of the first permanent molars (Salzmann[15]).

Pont's index can give an approximate indication of the degree of narrowness of the dental arches in a case of malocclusion, and also the amount of

lateral expansion required in order that the arch be of sufficient size to accommodate the teeth in perfect alignment (White, Gardiner, Leighton[19]).

Barnes[2], in a recent article dealing with expansion of deciduous arches, restates the need and usefulness of such a diagnostic method as Pont's Index.

Hays N. Nance[10] points out the fact that the sum of the average widths of the maxillary deciduous canine, first and second molars of one side equals .9 mm. more than the total of the mesiodistal widths of the three permanent teeth which succeed them. This difference is known as "leeway" space. The same sort of comparison in the mandibular arch, again using average mesiodistal widths, shows that the average leeway is 1.7 mm., nearly one millimeter more than the maxillary arch. Although the difference in size between the deciduous and permanent teeth is partially or wholly taken up by the natural forward positioning of the mandibular first permanent molars, the consideration of this leeway is of value in analyzing transition cases.

In permanent dentition analysis Nance uses a brass wire contoured to pass over the buccal cusps of the bicuspids and over the center of the ridge area in the anterior segment to determine arch length. The wire is cut at the mesial buccal line angles of the first molars; thus it represents arch length from first molar to first molar. Then, if there is a disparity of 5 mm. between arch length and tooth material, extraction is necessary.

In 1949 Neff[11] developed the "Anterior Coefficient" which was then obtained by measuring the sum of the mesiodistal diameters of the six upper anteriors and dividing into that the sum of the mesiodistal diameters of the lower six anteriors. This figure was called the Anterior Coefficient.

If the lower anterior teeth were in an upright position over basal bone and all other factors were normal in the case, a definite correlation was found to exist between the Anterior Coefficient and per cent of overbite.

He set up this table to correlate coefficient to per cent of overbite.

Coefficient	*Per Cent Overbite*
1.10	0
1.20	20
1.30	35
1.40	55
1.55+	100

Three hundred cases of malocclusion were used in this study. Neff came to the conclusion that, everything else being normal, an orthodontic or nonorthodontic normal will settle to the degree of overbite indicated by the Anterior Coefficient. However, he felt it would be necessary to measure many more normal occlusions to prove his thesis.

In a later paper Neff[12] analyzed a subsequent three hundred malocclusions. In this paper he used what is known as the "Anterior Percentage Relation" or A.P.R. Anterior Percentage Relation is the per cent acquired when the maxillary six anteriors are divided into the mandibular six anterior incisors. Actually, Anterior Percentage Relation is the reciprocal of Anterior Coefficient. Neff adapted his Anterior Coefficient to the Anterior Percentage Relation to more easily compare his results with other methods dividing upper teeth into lower teeth.

Thus, the sum of six hundred malocclusions was used to establish Neff's A.P.R. These cases were all measured directly in the patients' mouths.

Neff concluded that the maxillary six anteriors were 18 per cent to 36 per cent larger than the mandibular six anteriors. He points out that his ranges varied from those of Bolton[3] who examined excellent occlusions and

whose figures ranged from 24 per cent to 34 per cent.

In this paper Neff set up the following chart:

A.P.R.	*% Overbite*
10-18%	0
22	15
30	30
36	35
40	50
55	100

He pointed out that the anterior teeth had to come as close as possible to Downs'[4] rating of 135 degrees for upper incisor to lower incisor in order for the A.P.R. to be valid.

Two other analyses have been developed by Bolton[3]; in these he determines a ratio of mandibular tooth material to maxillary tooth material. By using this ratio and comparing it with his standard, the arch that is deficient is determined. The amount of the discrepancy is determined by referring to a table which predicts the amount of tooth material that the deficient arch should have.

From the amount of tooth material from first molar to first molar inclusive, a ratio is established by dividing the sum of the mandibular teeth by the maxillary teeth. If this ratio exceeds 91.3 per cent, the discrepancy is in excessive mandibular tooth material. If the ratio is less than 91.3 per cent, the mandibular tooth material may be assumed to be correct, and the discrepancy is in the maxillary arch of teeth.

For analysis of anterior teeth, the ratio of the sums of the six anteriors is established by dividing maxillary teeth into mandibular teeth. If the ratio exceeds 77.2, the discrepancy is in the mandibular arch. If it is less than 77.2, it is in the maxillary arch.

Bolton's mean, standard deviation and range for the analyses are shown by the following:

	Total Tooth Material	*Incisor Tooth Material*
Mean	91.3	77.2
S.D.	1.91	1.65
Range	87.5-94.8	74.5-80.4

These are the standards we will compare with our findings.

An ideal occlusion based primarily on the structural design of tooth forms has long been the standard of normal. Angle[1] derived this hypothetical ideal as a standard from his study of the morphology of the teeth. Strict adherence to the concept of an ideal normal occlusion has been severely criticized in recent years.

Normal occlusion of the teeth has been defined in this way: Occlusion of the teeth is normal when their manifold functions are efficiently performed and the health of the supporting structures is maintained. The primary functions of the teeth include mastication, esthetics, and functions of speech and deglutition (Hemley). However, there is no better way to refer to types of occlusions and to arrive at an understanding of the exact features involved than Angle's classification. It is obvious that the analyses so far discussed were based to a great extent on malocclusions. Therefore, it is the object of this study to test Pont's, Howes', Rees', Neff's, and Bolton's analyses on normal Class I dentitions. As pointed out by Angle, the perfect occlusion is rare. In this study cases with slight slipped contacts, minor rotations, or insignificant deviations from perfect occlusion were used. These cases were, however, considered in a group *separately* from the perfect samples. The two groups were classified as "normals" and "ideals" to see whether they showed any significant differences in their analyses.

Methods and Materials

This investigation was limited to model analyses that could be done with similar measurements and armamentarium, relating tooth material to basal bone.

All cases were normal Class I (Angle) adult dentitions selected from the models of fifty-seven dental students and eight Navaho Indians whose casts were on file at the College of Dentistry, Ohio State University. Bridges or missing teeth anterior to the second molar automatically disqualified the case. Cases with peg laterals or obvious anomalies were also discarded. Overjet and overbite had to be within acceptable limits; that is, up to about 2 mm. overjet, and no case with less than 1 mm. overbite or lower incisors exceeding the cingulum of the upper incisors when in centric occlusion. Cases with obvious diastema, reverse curves of Spee, buccal tipping of lower posterior teeth, lingual tipping of upper posterior teeth or anterior teeth were not acceptable. Obviously, any crossbite relation eliminated the case. In all, thirty-four normals and twenty-four ideals were studied.

The armamentarium used included protractor, Boley gauge, dividers, and tape.

All measurements and observations were made on plaster models in accordance with the methods prescribed by the authors involved (Figures 1, 2, 3).

Findings and Observations

The number of models used in this study was relatively small; therefore, the range for comparison with Pont's index covered only a portion of his table. However, the sample does reflect the range most likely to be encountered, which are the figures of greatest practical value. The figures reflected by the cases here ranged from 28.3 mm. combined mesial distal widths of the maxillary centrals and laterals to 34.6 mm., with the greatest concentration in the range 31 mm. to 31.5 mm. In statistical analysis of the ideals, computation for the regression equation revealed that a significant correlation existed between the combined incisor widths and the molar and upper premolar widths. No corresponding correlation could be found in the normals. The lower premolar width had no significant correlation to incisor width in either the ideals or the normals.

For Howes' analysis, the cases ranged from 37.5 to 51.5 for canine fossa to tooth material, with a mean of 43.43 and a standard deviation of 2.74 (Table I). Twenty-nine cases were less than 44 per cent; twenty-five cases were greater than 44 per cent; and none of the cases were less than 37 per cent.

In considering Rees' analysis, the upper base to upper teeth ranged from —5.3 to +10.3, with a mean of 0.31 and a standard deviation of 3.65 (Table II). Six of the cases exceeded Rees' maximum of +5, and thirty-seven were less than his minimum of +1.5.

Lower base to lower tooth material ranged from —3.7 to +8.6, with a mean of 2.83 and a standard deviation of 2.99. Rees' minimum of +2 was exceeded twenty-two times by quite a large differential.

In comparing upper base with lower base, the mean for the combined figures of the ideals and the normals was 7.07, with a standard deviation of 2.79 and a range from 1.5 to 12.4 (Table II).

The ranges for upper tooth material to lower tooth material were 2.4 to 13.8 mm., with a mean of 9.61 and a standard deviation of 2.05. Rees' maximum of +10 mm. was exceeded

TABLE I

HOWES' ANALYSIS COMPUTATIONS

	Canine Fossa / *Tooth Material (Normals)*	*Canine Fossa* / *Tooth Material (Ideals)*	*First Bicuspid Arch Width* / *Tooth Material (Normals)*	*First Bicuspid Arch Width* / *Tooth Material (Ideals)*
Number	34	21	34	21
Mean	43.66	43.05	42.44	43.08
Standard Deviation	2.95	2.38	1.81	1.19
Largest	51.5	46.5	46.9	45.8
Smallest	39.3	37.5	38.8	40.3

	Canine Fossa / *Tooth Material (Ideals + Normals)*	*First Bicuspid Arch Width* / *Tooth Material (Ideals + Normals)*
Number	55	55
Mean	43.43	42.72
Standard Deviation	2.74	1.61
Largest	51.5	46.9
Smallest	37.5	38.8

twenty-three times; however, his minimum of +5 mm. was never exceeded.

In Bolton's analysis of the percentage of mandibular tooth material to maxillary tooth material, there was no apparent difference in the ideals from that of the normals. The sample ranged from 87.2 to 94.6, with a mean of 91.04 and a standard deviation of 1.90. There was, however, a difference between the percentage of the mandibular six anteriors to the maxillary six anteriors when comparing ideals to normals. The ideals ranged from 72.5 to 81.7 per cent, with a mean of 77.55 and a standard deviation of 2.72. The normals ranged from 73.9 to 83.3 per cent with a mean of 78.59 and a

TABLE II

REES' ANALYSIS COMPUTATIONS

	Upper Base to Upper Teeth (Ideals & Normals)	*Upper Base to Lower Base (Ideals & Normals)*	*Lower Base to Lower Teeth (Ideals & Normals)*	*Upper Tooth Mat. to Lower Tooth Mat. (Ideals & Normals)*
Number	56	54	55	56
Mean	0.31	7.07	2.83	9.61
Standard Deviation	3.65	2.79	2.99	2.05
Largest	10.3	12.4	8.6	13.8
Smallest	—5.3	1.5	—3.7	2.4

TABLE III
BOLTON'S ANALYSIS COMPUTATIONS

	% Mand. Teeth / Max. Teeth (Normals)	% Mand. Teeth / Max. Teeth (Ideals)	% Mand. Ant. Teeth / Max. Ant. Teeth (Normals)		% Mand. Ant. Teeth / Max. Ant. Teeth (Ideals)
Number	34	23	34		22
Mean	91.10	90.94	78.59		77.55
Standard Deviation	1.79	2.08	2.37		2.72
t				1.510	
Largest	94.6	94.2	83.3		81.7
Smallest	87.9	87.2	73.9		72.5

	% Mand. Teeth / Max. Teeth (Ideals + Normals)	% Mand. Ant. Teeth / Max. Ant. Teeth (Ideals + Normals)
Number	57	56
Mean	91.04	78.18
Standard Deviation	1.90	2.54
Largest	94.6	83.3
Smallest	87.2	72.5

standard deviation of 2.37 (Table III).

Discussion

By plotting the combined widths of the maxillary centrals and laterals to the arch widths of the maxilla and mandible in the bicuspid and molar regions, scattergrams were produced in which the ideal occlusions formulated a curve, falling quite close to that predicted by Pont's index. A similar comparison for the normals was much more difficult to demonstrate because of the greater range of measurements encountered. These curves all fell below those predicted by Pont's index. Arch width measurements of the molar area were found to be the same in the maxilla and the mandible; therefore, no calculations were made for lower molar arch width.

Apparently the findings here paralleled Pont's figures. It is significant that there was a definite correlation found in the ideals between anterior tooth size and arch width. The normals did not correlate and had such a large range that it would be fallacious to assume that every case must be regulated to the measurements predicted by Pont's index in order to be successful. However, Pont's measurements should be a goal to strive for when working toward the ideal.

Pont's sample was composed entirely of persons of French nationality. Ours was done on Americans of many different national groups. This may possibly be the reason our normals did not agree with Pont's figures.

It was observed that the points used in measuring the arch width of the maxilla in the first bicuspid area were more difficult to locate than those in the mandible, and that these two measurements were not equal.

In Howes' analysis there was no difference between the ideals and the

normals when compared graphically, and both were in agreement with Howes' figures. Apparently Howes' theory that canine fossa cannot be exceeded by the bicuspid arch width is not valid. True, it was found that the mean of the upper bicuspid arch width did not exceed canine fossa statistically; however, in actual count the canine fossa was exceeded in sixteen cases out of fifty-five. Perhaps our findings differ from Howes' on this point because in all of his measurements only fourteen normal occlusions were considered, whereas all of our measurements were done on normal occlusions.

It would be interesting to make a study by using Howes' analysis of C.F. and correlate it with Pont's lower arch width. Pont's measurement of the mandibular arch width in the bicuspid area was always less than that of the maxilla and was never more than that of the canine fossa. By this method the lower arch could be correlated to the upper arch; Howes' analysis has been criticized because it does not do this.

Howes believes that because the maxillary teeth overlap the mandibular teeth they are in control of the shape and size of the lower arch. It would seem from the findings of this study that the maxillary basal bone controls the lower dental arch, and it in turn controls the upper dental arch.

In this study, eight cases of Navaho Indians were included. In seven of these eight, the canine fossa was exceeded by the bicuspid arch width. Could environment be the reason or is it the hereditary pattern of the ethnic group?

In considering Rees' analysis, the normals and the ideals all compared graphically quite similarly except when considering upper base to lower base, and this comparison showed only a slight difference. Ninety per cent of the ideals ranged from 5.3 to 10.5. Ninety per cent of the normals ranged from 1.9 to 11.2. The ideals did not exceed Rees' range for the minimum amount of 3 mm. but did exceed his maximum amount of 9.5 mm. in a few cases by 1 mm. A few of the normals exceeded both the maximum and the minimum.

When Rees' analysis was compared with the normal and ideal, there was a lack of agreement on the limits involved. The cases tested here indicated that Rees' ratings, changed to the nearest .5 mm., should be as follows:

	Mean	*Minimum*	*Maximum*
U.B.-U.T.	+ .5	—3.5	+ 4
L.B.-L.T.	+3	0	+ 6
U.B.-L.B.	+7	+4.5	+10
U.T.-L.T.	+10	+8	+12

Thus, in using these newer values, Martinek's criteria of 7 mm. discrepancy between U.B.-U.T. as the extraction limit could be reduced to about 4 mm. which correlates much more closely with Nance's limit of 5 mm.

Rees' sample consisted of "twenty normal non-extracted cases," which does not describe his sample in much detail; this may be the factor accounting for the difference in our findings.

Bolton's percentage relationship of lower tooth material to upper tooth material compares exceptionally well with the percentage found here.

	Bolton	*Ideals and Normals*
Mean	91.3	91.04
Standard deviation	1.9	1.90
Range	87.5-94.8	87.2-94.6

For the anterior percentage relationship the ideals came very close to Bolton's figures. Conversely, the normals did not correlate with his figures.

	Bolton	*Ideals*	*Normals*
Mean	77.2	77.55	78.59
Standard deviation	1.65	2.72	2.37
Range	74.5-80.4	72.5-81.7	73.9-83.3

Neff used six hundred malocclusions and arrived at a mean of 79 per cent which would not agree with our mean of 77.55. The mean of 77.2, found by Bolton on excellent occlusions is in agreement with our figure. This is gratifying in view of the fact that both samples were similar; that is, both were samples of normal occlusions.

It is obvious that the percentage relationship of the lower to the upper anterior tooth size is a vitally significant consideration to make when attempting to harmonize tooth material.

Conclusions

A statistical test was applied to fifty-eight cases of ideal and normal occlusions to note the validity of Pont's, Howes', Rees', Neff's, and Bolton's analyses.

In Pont's analysis there was a significant correlation existing between the combined incisor widths and the molar and upper premolar widths in the ideal occlusions, but not in the normal occlusions.

Howes' analysis showed the mean per cent of canine fossa to tooth material to be 43.43, with a standard deviation of 2.74 and a range of 37.5 to 51.5, which compares favorably with his figure of 44 per cent.

Rees' figures should be changed to—

	Mean	*Minimum*	*Maximum*
U.B.-U.T.	+ .5	—3.5	+ 4
L.B.-L.T.	+3	0	+ 6
U.B.-L.B.	+7	+4.5	+10
U.T.-L.T.	+10	+8	+12

Bolton's percentage relationship for lower tooth material to upper tooth material of 91.3 agrees with that found here. The anterior percentage relationship of 77.55 also compares favorably with what was found by him.

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Forces Exerted On The Dentition By The Perioral And Lingual Musculature During Swallowing*

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Does the perioral and lingual musculature have an effect on the positioning of the teeth? If it does, to what degree does it dominate the dentition and consequently govern orthodontic results? If it does not, what factors are paramount in this equation? Are these myometric forces primary or secondary, causative or adaptive?

These questions have perplexed the orthodontic profession from its inception and, even today, represent some of the most critical considerations for future progress.

Early attempts at describing the effect of the musculature on the dentition, although somewhat erroneous, have served to stimulate an appreciation for the multitude of components which constitute the whole masticating mechanism. The sterile static approach to orthodontics, pervading the profession for so long, is slowly being replaced by a dynamic functional concept.

Teleological reasoning blended with a comprehensive knowledge of the basic sciences has and always will provide the initial thrust needed for scientific advancement. But only acceleration is thus provided; direction and reliability must in each instance be secured by experience and carefully collected data. Although reliable evidence is slow in accruing, some of the answers appear to be forthcoming.

The not too distant future may hold promise for the progressive orthodontist with a pragmatical knowledge of the musculature which will unquestionably reflect itself in the quality of the service he renders. The future may also hold for some a denial of the use of that mystical waste-basket which catches so many treatment failures and nebulous phenomena within the oral cavity.

Interest is growing in this field of study with an increasing number of reports appearing in the literature. The appeal of these studies can unquestionably be attributed to the directness of their approach. The electromyograph, although invaluable, can never have this attribute.

Since the publication of the initial investigation of oral myometric pressures by this author[1], a constant effort has been made to refine instrumentation and procedure and this project presents the findings on one aspect of the whole problem.

Instrumentation

The possibility of constructing an efficient pressure recording instrument, a dynograph, based on a principle of inductance, reluctance or capacitance was investigated. The results of these studies have proved to be most revealing.

It should be mentioned, at this point, that it has been the contention of this

*This investigation was supported by a research grant from the Division of Research Grants and Fellowships of the National Institutes of Health, United States Public Health Service.

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investigator, in order to obtain the maximum in sensitivity and reliability, that a dynograph must be employed in which the transducer can be placed directly in the mouth. The validity of this approach will be pointed out later.

A beat-frequency oscillator-recorder was tested along with inductance and reluctance dynographs. Flat coils, paired inductance coils and coils of varying designs, capable of being placed in the mouth, were tested. Various wire diameters (35, 44 and 47 gauge) were utilized, but the induction of the coils was of such low magnitude that high frequency oscillators (over 2 megacycles) had to be used for sufficient sensitivity. At such high frequency the problem of capacitance changes occurring in the lead wires was encountered when parts of the body or lips were brought in contact with them. These changes were of the same magnitude as the changes effected in the transducers. Coaxial cable lead wires small enough to be used in the mouth for the purpose of this research are not manufactured, nor was it deemed practical after consulting various wire manufacturers.

Every attempt was made at reducing the capacitance sensitivity of the lead wires to an insignificant point by increasing the inductance of the coils, thereby allowing a lower frequency oscillator to be used. Transducers, employing smaller diameters of magnet wire, more turns in the coils (up to 200), with and without iron core, were tested. The induction of the coils was increased only to the extent that a 50 kilocycle oscillator was needed. The change in capacitance induced by body contact with the lead wires was greatly reduced, but still represented an apparently overwhelming problem.

An induction recorder requiring a primary and secondary coil for the transducing element was investigated. Different transducers were tested employing various sizes of coils, turns and diameters of wire. However, since the size of the transducer is necessarily restricted, larger coils which would allow for sufficient change in inductance could not be utilized.

Capacitance transducers have the same inherent limitations as inductance transducers. These investigations indicate that transducers employing inductance, reluctance or capacitance principles are not suited to this type of research.

Methods

The feasibility of utilizing a resistance transducer (SR-4 strain gage) with a suitable amplifier-recorder has been established by the author[1] and, in general, the construction of the transducer and procedure follows closely to that previously described.

Certain refinements were incorporated, however, in design and sensitivity. Among the most important was the elimination of the temperature compensating gage. This permitted the use of only one gage which allowed for considerable decrease in size of the mouthpiece and simplification of its construction. Upon consultation with the Baldwin-Lima-Hamilton Corporation, it was pointed out that since the maximum range of temperature variability would be 17° centigrade and considering the temperature coefficient of the strain gage itself, any inaccuracy due to changes in temperature of the strain gage wire would be limited to less than .03%.

Stability experiments later proved the practicality of using only one strain gage in the transducer if sufficient time for temperature stabilization is provided before balancing the bridge and the collection of data.

A different design was employed in the construction of the transducer from

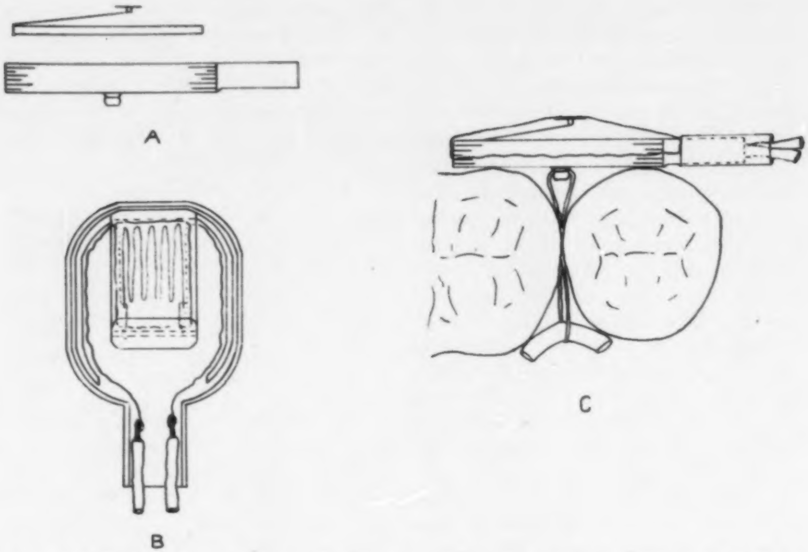

Fig. 1 A—Design of gage carrier, B—Strain gage mounted on gage carrier, C—Mode of attachment to teeth.

that previously used. Figure 1 represents a schematic drawing of its construction and placement in the mouth. The gage carrier seen in drawing A of Figure 1 was cast in gold. A small hook was soldered to its back which was used in securing the mouthpiece to the teeth. The cantilever beam to which the strain gage is applied was constructed in spring steel. It measured 3 millimeters wide, 4 millimeters long and 0.1 millimeters in thickness. It was designed with a recurved pressure receiving button which measured 2.5 millimeters by 3 millimeters. The strain gage (A-19) was applied to the top of the active beam, thus recording a tensile strain and the wires from the strain gage were re-curved and secured to the bottom of the active beam. They were then positioned along the sides of the gage carrier and continued to be soldered to the lead wires. Insulation against moisture was accomplished by cementing a small piece of rubber dam material over the top of the transducer and securing the rubber dam to the sides of the gage carrier. A small piece of polyethylene tubing was slipped over the gage carrier end to further insulate against moisture and to prevent excessive bending in the lead wires. The polyethylene tubing was then filled with liquid latex rubber.

The dimensions of the cantilever beam were previously mathematically computed in order that the transducer would be sensitive in the range of from 0 to 50 grams, these figures having been established by the author's earlier investigations.[1]

Various strain gages, namely the C-19, A-18, AB-19, AB-18 were investigated, but again the A-19 strain gage seemed to be the most suitable because of its size and ease of manipulation.

Transducers employing the A-19 gage

and the A-18 gage were constructed. Since the A-19 gage is a 60 ohm resistance gage, a 40 ohm resistor was added in series to bring the total resistance into the designed range of the recorder. As was to be expected, this rendered this transducer slightly less sensitive than the transducer employing the 120 ohm, A-18 gage. Repeated calibrations at the highest attenuation for the A-19 transducer gave a regression coefficient of $b = .60$, or 1 gram load $= .60$ lines deflection, computing the standard error of estimate, $Sy = .694$ lines. Repeating the same calibration for the transducer employing the 120 ohm gage at the most sensitive attenuation, the regression coefficient was found to be $b = .66$, or 1 gram load equals .66 lines deflection. The standard error of estimate for these values was $Sy = 1.094$ lines.

The recorder which was used in this project was a model 141-T Sanborn recorder and strain gage amplifier. This recorder is designed to function with strain gages having a nominal resistance in the range of 100 to 120 ohms. It is a one unit amplifier-recorder and employs a heated stylus which has proved to be most satisfactory. It contains the usual strain gage attenuation adjustments and, although it contains a dual speed recorder, all the records were obtained at a speed of 2 millimeters per second.

The areas in which the perioral and lingual myometric pressures were recorded were: the interproximal between the maxillary and mandibular central incisors, and the interproximal between the maxillary and mandibular second bicuspids and first permanent molars. Thus, it was possible to obtain the pressures exerted on the anterior teeth, both maxillary and mandibular, by the tongue and the upper and lower lips. Also, it was possible to measure the lateral pressures on the buccal segments of the maxillary and mandibular teeth by the tongue and the cheeks.

Instead of securing the mouthpiece to the teeth by the use of wire around the contact points, which had been previously used, it was found to be a valid approach, both from the standpoint of facility and stability, to use a very small rubber elastic which was fastened to the hook on the back of the gage carrier, slipped below the contact points of the teeth and held in position by a small piece of rubber tubing on the opposite surface of the teeth.

Twenty-five subjects were used for this investigation and their occlusions classified using the conventional Angle classification. One group of eleven subjects with clinically excellent occlusions constituted the normal subjects. Ten subjects were classified as having Class II, Div. 1 malocclusions. Two subjects with Class I malocclusions exhibited anterior open bites. There were one Class II, Div. 2 and one Class III malocclusion subjects also included. The mean age of the subjects was 26 years and varied from 22 to 35 years. Only white male adults were used for this study.

The discipline for the collection of the data on these subjects was as follows: The operational procedures used for the recorder were those supplied by the Sanborn Company for the 141-T recorder and this included at least a one-half hour warm-up period prior to any recordings. After placement of the mouthpiece, a period of at least three minutes to allow for temperature stabilization was allowed to elapse before balancing and calibrating the recorder. The tissue over the transducer was reflected and. after balancing and calibration had been accomplished, the tissue was released and the first recording was a resting pressure.

The tissue was again reflected and resting pressure was recorded for at least three times. This then became the base line to which the needle returned after each of the following functional exercises.

The swallowing exercises were instigated in each of the areas and an attempt was made to simulate a physiologic or normal swallowing reflex as much as possible. At all times the patient was instructed to disregard the presence of the mouthpiece and to make only those movements which seemed natural to him. This was done by having the patient swallow as casually as possible on command. After the first swallow had depleted the saliva supply in the mouth, two to three cc. of room temperature water were taken into the mouth by the subject to reinforce the saliva supply for each successive swallowing attempt. All pressure recordings were repeated three or four times in every area to evaluate the reliability of the values obtained.

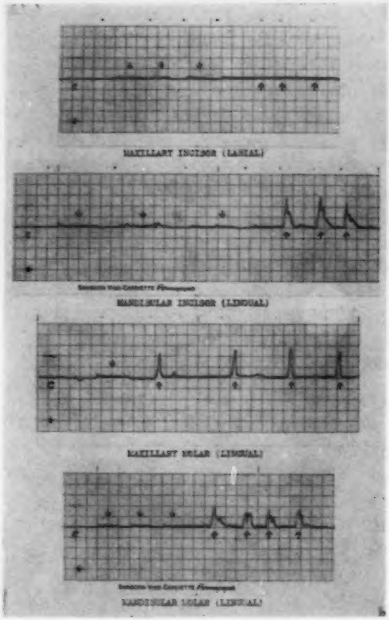

Fig. 2 Sample oscillograph records. C—Calibration, vertical arrows, above record line indicate resting pressures; below record line indicate time of swallowing.

Results

Sample oscillograph records are shown in Fig. 2. Not all of the labial and buccal areas are included, but the record for the maxillary incisor (labial) is typical for most perioral recordings.

After the graphic records were accumulated on the subjects, they were analyzed, and the deflections or peaks during swallowing and at rest were converted into pounds per square inch values. Table I represents the presence or absence of pressure during rest on the eight areas which were surveyed on each subject.

During all of the recordings during rest, the deflection never exceeded one line and for the most part no attempt was made to distinguish more than one-half a line variation on any of the recordings. It is interesting to note that in the majority of cases there was an absence of resting pressure on the lingual surfaces of the maxillary central incisors. It is also interesting to note from Table I that quite frequently there was an absence of resting pressure on the lingual surfaces of the mandibular central incisors.

Table II presents the pressures recorded in the same areas for the various subjects during the swallowing exercises. Table II also discloses that there was no pressure brought to bear against the labial surface of the maxillary or mandibular central incisors, except in the cases where there was an open bite or an opening between the anterior teeth in occlusion.

In order to evaluate the presence or absence of a correlation between the position of the teeth and the pressures brought to bear on them by the perioral

TABLE I

RESTING PRESSURES

No. Of Subjects	*Type Of Occlusion*	*Maxillary Central Incisor* *Labial*	*Lingual*	*Mandibular Central Incisor* *Labial*	*Lingual*	*Maxillary Molar Area* *Buccal*	*Lingual*	*Mandibular Molar Area* *Buccal*	*Lingual*
11	Clinically Excellent	X	0	X	8 - X 3 - 0	X	X	X	X
2	Class I — Ant. Open Bite	X	1 - X 1 - 0	X	1 - X 1 - 0	X	X	X	X
8	Class II—Deep Ant. Overbite	X	0	X	6 - X 2 - 0	X	X	X	X
2	Class II Div. 1 No ant. Overbite	X	0	X	X	X	X	X	X
1	Class II Div. 2	X	0	X	X	X	X	X	X
1	Class III	X	X	X	X	X	X	X	X

(X = up to .352 psi pressure)
(0 = absence of resting pressure)

and lingual musculature, the angular positions of the anterior teeth were evaluated by cephalometric radiographs which were taken on each of the subjects. The angular measurements for the maxillary central incisors and the mandibular central incisors were measured to the NS line and the GoGn plane respectively. Other angular cephalometric measurements were checked as to possible correlations; also, a millimetric appraisal of the width of the arch measured directly in the mouth from the lingual surface of the maxil-

TABLE II

SWALLOWING PRESSURES

No. Of Subjects	*Type Of Occlusion*	*Maxillary Central Incisor* *Labial*	*Lingual*	*Mandibular Central Incisor* *Labial*	*Lingual*	*Maxillary Molar Area* *Buccal*	*Lingual*	*Mandibular Molar Area* *Buccal*	*Lingual*
11	Clinically Excellent	0	0	0	X	0	X	0	X
2	Class I — Ant. Open bite	Sl.	X	Sl.	X	1-Sl. 1-0	X	0	X
8	Class II Div. 1 Deep Ant. Overbite	2-Sl. 6-0	0	1-Sl. 7-0	X	0	X	0	X
2	Class II Div. 1 No Ant. Overbite	Sl.	X	Sl.	X	1-Sl. 1-0	X	0	X
1	Class II Div. 2	0	0	0	X	0	X	0	X
1	Class III	0	X	0	X	0	X	0	X

(X = significant pressure increase — Range .587 to 10.138 psi)
(Sl. = slight pressure increase — less than .352 psi)
(0 = no pressure increase)

lary right first molar to the maxillary left first molar was made. The length of the dentition and height of the palate were appraised from cephalometric radiographs. The length was measured from the mesial surface of the maxillary first permanent molars to the incisal edge of the mandibular incisors, or in the case of the anterior open bite subjects, to the incisal edge of the maxillary central incisors. The height of the palate was measured at a point on the occlusal plane at the mesial of the maxillary first permanent molars, perpendicular to the palatal plane as it intersects the oral surface of the palate.

It was found that the average coefficient of variation of all the pressures in the various areas for all the subjects was 14 per cent. This could possibly be considered in general to represent the ability of the subjects to reproduce their own pressures under the discipline which was previously described.

As was pointed out earlier, the standard error of estimate, which may serve the same purpose as the standard deviation for the regression coefficients computed for the calibration of the recording instrument, was accurate within one-half line variation. This means that the recording instrument is far more accurate than the patient's ability to reproduce his own pressures. In order to statistically analyze any significant variation between the pressures obtained in the normal group, as opposed to the malocclusion group, "t" ratios were computed for three areas. These areas were the lingual of the mandibular central incisors, the lingual of the maxillary molar area and the lingual of the mandibular molar area. There were eleven subjects in the normal group and ten subjects in the Class II group and the pressures used were the mean swallowing pressures. These comparisons along with means, standard deviations and standard error of means are presented in Table III.

Not only are the "t" ratios, Table III, insignificant, but also the various areas within the group of subjects when compared in this manner.

The coefficient of correlation was computed for the swallowing pressures of each subject and those values which reflect the position of the teeth. The group was considered as a whole; however, correlation coefficients also proved to be insignificant when comparing the excellent occlusion group and the Class II, Div. 1 malocclusion group separately.

TABLE III

COMPARISON OF SWALLOWING PRESSURES BETWEEN GROUPS

	Class I Excellent Group			*Class II Div. 1 Group*			
	Mean	*Standard Deviation*	*Standard Error*	*Mean*	*Standard Deviation*	*Standard Error*	"t"
Lingual-Mandibular Central Incisor	2.828	2.143	.646	3.673	1.065	.337	1.125
Lingual-Maxillary Molar Area	2.644	1.271	.383	4.113	3.095	.978	1.453
Lingual-Mandibular Molar Area	2.638	.972	.293	2.979	.998	.315	.796

t.05 loc = 2.093
(pressures in pounds per square inch)

Discussion

Concerning the instrumentation of this project, it was a distinct advantage to use only one strain gage in the transducer. This has resulted in a smaller mouthpiece and the elimination of a third lead wire, thus insuring more physiologic recordings. The method of attachment of the mouthpiece to the teeth proved to be more efficient without sacrificing stability and reliability.

The importance of placing the transducer in the mouth to receive the myometric pressures directly has been pointed up dramatically in this study. From Table II it will be noted the lingual pressures during swallowing ranged from .581 psi to 10.138 psi. In a study on maximum forces, Kydd[2] reports values which were apparently not significantly larger than those obtained in this study for swallowing pressures. This could be explained on the basis of the instrumentation. Recording apparatus involving wafers or bulbs and connecting tubing have certain inherent disadvantages which render them somewhat unreliable in this pressure range. The flexibility of the tubing and the compressibility of the air or liquid media within the system are a big source of error.

The resting pressures for the various subjects seem to indicate that the tongue position is such that there is no contact made with the lingual surfaces of the maxillary incisors, at least in excellent dentitions, or in Class II malocclusions with deep anterior overbite.

Of particular significance is the finding that in some cases there is no resting pressure on the lingual surfaces of the mandibular incisors. The importance of this fact is compounded by the fact that these same subjects do not compensate by a large functional pressure in this same area. A study utilizing a transducer sensitive within the resting pressure ranges is necessary to validate this implication.

Swallowing pressures recorded in this study have indicated quite dramatically that the perioral musculature does not normally contract during swallowing in subjects with excellent dentitions. It further indicates that subjects in which a Class II occlusal or skeletal relation exists, and who can form an anterior seal when the teeth are occluded, do not contract the perioral musculature during swallowing.

It seems apparent that only in cases in which there is an anterior opening or open bite — instances in which the dentition cannot seal itself in occlusion — does the perioral musculature contract at all. The net pressure against the anterior teeth was not remarkable.

A tongue thrust, as recorded by pressure on the lingual surfaces of the maxillary incisors, was present in each of the cases of perioral muscular contraction. Even though the collective occurrence or syndrome of anterior open bite, perioral muscular contraction and tongue thrust can be demonstrated, the exact relation from an etiologic standpoint is relegated to that of logic. If we accept the basic premises that teeth seek occlusal antagonists, be it teeth or palate — and that in the infant before eruption of teeth there is a normal contraction of perioral musculature associated with a tongue thrust, we can validly argue the tongue thrust is primary or causal in nature. Ontogenetically, we may look at this syndrome as a prolonged infantile swallowing reflex in which the tongue thrust does not allow the anterior teeth to erupt.

Needless to add, tongue thrust is not the only cause of anterior open bite. An inadequacy or arrest of condylar growth and habits, among others, must always be considered.

Tongue thrust, therefore viewed

TABLE IV

(Correlation of Swallowing Pressures — Position of Teeth)

	$\overline{1}$ to GoGn	*$\underline{1}$ to NS*	*Length of Arch*
Mandibular Central Incisor Lingual Pressures	r = .204	r = —.262	r = —.233
	Width of Arch	*Height of Palate*	
Maxillary Molar Area Lingual Pressures	r = .023	r = —.146	
	Width of Arch	*Height of Palate*	
Mandibular Molar Area Lingual Pressures	r = —.090	r = —.195	

r.05 loc = .396

ontogenetically, might well be removed from the classification of habits since this word carries a connotation of adoption or acquisition. Tongue thrust may also develop secondarily to a primary cause — the differential diagnosis of which may prove to be significant in orthodontic management and prognosis.

It should be noted that although the recordings for each subject were reproducible, there seemed to be significant variations within the normal group as in the Class II, Div. 1 malocclusion group. The "t" ratios, Table III, proved to be insignificant when pressures from one area were compared with pressures in a different area when the sample was considered as a whole.

Table IV indicates insignificant correlation coefficients when comparing the swallowing pressures with the bucco-lingual axial relationships of the teeth.

Although peak mean pressures are used and compared with those values reflecting the positions of the teeth, the extremes in the pressure ranges were also tested as to possible correlation, along with various methods of assessing bucco-lingual position of teeth. Every instance failed to disclose a significant correlation.

These findings have been corroborated by Stevens[3] and Sims[4]. Although their values differ somewhat from the ones recorded in this study, which may be due to the difference in instrumentation which was previously described, they also found a lack of correlation between swallowing pressures and the position of the teeth.

The movement of the tip of the tongue during swallowing appears to be determined by the position of the mandibular incisor teeth. This is true both in an anteroposterior aspect as well as an inferosuperior position. In the Class III malocclusion, Table II, there was considerable lingual pressure recorded on the maxillary central incisors.

What then may we conclude at this point in myometric research? Certainly the following statement appears valid in the light of the evidence to date:

During function, there is an imbalance of myometric forces acting on the dentition — the tongue exerting a much greater force than the perioral musculature.

Conclusions

1. Recording instruments employing inductance, reluctance, or capaci-

tance principles are not suited for recording perioral and lingual myometric pressures.

2. Resistance transducers and recorders are best suited for recording myometric pressures.
3. Resting and swallowing pressures were recorded on subjects with normal occlusions and malocclusions; the reliability and practicality of the recording instrument and the procedure used have been proven.
4. Many refinements in the construction and manipulation of the strain gage transducers were formulated.
5. Mean pressures and standard deviations were established for subjects with normal dentitions and malocclusions in different areas of the mouth during swallowing.
6. Certain concepts regarding tongue position during rest were formulated.
   a. The tongue is not held in contact with the lingual surfaces of the maxillary central incisors during rest, except in Class III and some anterior open bites.
   b. Frequently there is a lack of resting pressure from the tongue against the lingual surfaces of the mandibular central incisors.
7. Certain concepts regarding the swallowing reflex were formulated by this investigation:
   a. The buccal and labial musculature does not contract during swallowing unless there is an anterior open bite or lack of anterior overbite with accompanying anteroposterior skeletal dysplasia.
   b. A tongue thrust during swallowing can be the cause, not the result of the anterior opening.
   c. The tip of the tongue is placed behind the lingual surfaces of the maxillary central incisors during the act of swallowing, and not brought in contact with the central incisors in normal occlusions or malocclusions with deep overbite.
8. There is no statistically significant difference between the pressures incurred during swallowing in the normal group, as opposed to the Class II, Div. 1 malocclusion group.
9. There is no statistically significant correlation between the swallowing pressures and the anteroposterior position of the teeth.
10. In function, the tongue exerts a much greater force on the dentition than does the perioral musculature.

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Estimation Of The Sizes Of Unerupted Cuspid And Bicuspid Teeth

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A survey of the orthodontic literature for the last few years indicates increased interest in beginning orthodontic treatment during the period of the mixed dentition. The trend toward earlier treatment reflects better comprehension of malocclusions and their diagnosis. In terms of treatment, Kloehn's[1] revival of extraoral anchorage and Kjelgren's[2] introduction of serial extraction exemplify better understanding of the strengths and limitations of current appliance therapy. Some of the concepts underlying these therapies are: 1) relative stability of arch width in the untreated case after the eruption of the permanent incisors, 2) slight decrease in mandibular arch length anterior to the permanent molars, 3) inability of appliance therapy to measurably influence more than the teeth and their immediate supporting tissues, and 4) undesirable effects from extensive use of mandibular anchorage. In a recent paper, Weber[3] provided an excellent review of the concepts of mixed dentition diagnosis and treatment.

As pointed out by Nance[4], diagnosis during the mixed dentition hinges to a large extent on analysis of the lower arch. From this viewpoint, diagnostic variables to be considered are: 1) crowding or spacing present in the mandibular arch in the mixed dentition, 2) difference between the size of unerupted cuspids and bicuspids and space in the mandibular arch available for them, 3) inclination of the incisors, 4) expected slight increase in arch width, and 5) the expected slight decrease in arch length anterior to the permanent molars. Of the five considerations listed, perhaps the first two show the greatest variability and, as a result, receive the most attention in diagnosis and treatment planning.

Nance[4], Ballard & Wylie[5], Carey[6], and Griewe[7] have previously given consideration to the problem of predicting the size of the mandibular cuspids and bicuspids before their eruption and have developed useful techniques for this purpose. The primary objective of this investigation was to determine if a more efficient procedure could be found, i.e., if error in prediction could be reduced further. A byproduct, pertinent to analysis of the mixed dentition, was study of the relationship between size of the permanent cuspids and bicuspids and size of their deciduous predecessors.

The efficiency of the twelve procedures in predicting the size of teeth 3, 4, and 5 was explored by correlating the combined width of 3, 4 and 5 with the variables listed in Table I. To evaluate this series of relationships it was necessary to collect material for each subject which met the following requirements:*

The investigative portion of this paper was supported in part by a research grant, D-217, from the Institute for Dental Research of the National Institutes of Health, Public Health Service.

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**Based on a thesis submitted in partial fulfillment for the Master of Science degree, State University of Iowa, February 1956.

(1) A cast of the lower arch with c, d, and e present, and free from proximal carious lesions or restorations on one side of the arch.

(2) Periapical x-ray film of the same side as above, taken the same date as the impression for the cast, with c, d, and e present and erupted; with 3, 4, and 5 present but unerupted.

(3) A later cast with 3, 4, 5 and 2, 1, 1, 2 erupted; with no proximal carious lesions or restorations on the side measured previously.

A sample of forty one children, fifteen males and twenty-six females, from the Facial Growth Study at the State University of Iowa met the above requirements. All were American-born and of predominantly northwest European ancestry. The teeth were measured on hydrocal casts obtained from alginate impressions. The intraoral x-ray films used were taken by a technician using a conventional dental x-ray machine fitted with a cone giving a 16 inch skin-target distance.

The cast measurements of the mesial-distal diameter of the deciduous teeth and the x-ray measurements of c, d, e, and 3, 4, 5 were made within one year of the shedding of c, d, and e. The age range for these measurements was from 7 years, 6 months to 11 years. Tooth measurements of the permanent teeth of the same individuals were obtained from casts taken between 12 and 15 years of age.

TABLE I

Correlations between the combined widths of erupted 3, 4, and 5 and the combined widths of several combinations of cast, film, or cast and film measurements. N = 41 unless otherwise noted.

Combined widths of 3, 4, and 5 correlated with:	*r*
c, d, e cast	.56
1, 2, 2, 1 cast	.69
3, 5 x-ray film	.78
4, 5 x-ray film	.80
3, 4 x-ray film	.82
3, 4, 5 x-ray film	.82
1, 2, 2, 1 cast plus c, d, e cast	.75
3, 4 x-ray film plus 1, 2, 2, 1 cast	.84
3, 4, 5 x-ray film plus 1, 2, 2, 1 cast plus c, d, e cast	.85
4, 5 x-ray film plus 1, 2, 2, 1 cast	.88
4, 5 x-ray film plus 1, 2 cast	.88*
4, 5 x-ray film plus 1, 2 cast	.87**
4, 5 x-ray film plus 1, 2 cast	.82***

*The multiple correlation (R) using 3, 4, 5 cast as the dependent variable, with 4, 5 (x-ray) and 1, 2 (cast) as the independent variables, is .88.

**N=76, films taken between 7½ years and 11 years of age.

***N=76, all films taken at 8 years of age except two taken at 7½ years.

For all teeth the maximum mesial-distal diameters of the crowns of the individual teeth were measured at right angles to the long axis of the tooth. A finely pointed, standardized Boley gauge was used throughout. Where teeth were rotated before eruption, the maximum crown diameter on the films measured at right angles to the long axis was considered as the width of these teeth.

Two independent measures were recorded for each tooth. If the two measures agreed within 0.1 mm, the average of the two was used. If disagreement exceeded 0.1 mm, two more independ-

*The following method of designating the mandibular teeth will be used throughout this paper:

1—permanent central incisor
2—permanent lateral incisor
3—permanent cuspid
4—1st bicuspid
5—2nd bicuspid
c—deciduous cuspid
d—deciduous 1st molar
e—deciduous 2nd molar
Width=maximum mesial-distal diameter

ent measures were taken and the four averaged. Product-moment correlation coefficients of $r = .97$ and $r = .99$ indicate the high reliability of the two original cast and film measurements.

Associations for the combined widths of 3, 4, and 5, and each of twelve predictive combinations were obtained by preparing scattergrams and computing Pearson product-moment correlation co-efficients (r). The obtained values are given in Table I. One additional approach, an attempt to correct for enlargement of 3, 4, and 5 on the film by the ratio $\frac{\text{cast c, d, e,}}{\text{x-ray c, d, e}}$ gave such wide dispersion on the scattergram that the correlation coefficient was not computed. Surprisingly, of the other relationships studied, the weakest was that between the size of the deciduous posteriors c, d, and e, and 3, 4, and 5 ($r = .56$). The relationship ($r = .69$) between the lower permanent incisors and 3, 4, and 5 is in close agreement with that reported by Ballard and Wylie[5], and by Griewe[7]. The strongest relationship found ($r = .88$) is that between the cast widths 1 and 2 plus the film widths of 4 and 5 correlated with 3, 4, and 5 when they had erupted. A stronger relationship could not be demonstrated by use of multiple correlation.

The width of 1 and 2 plus the x-ray measure of 4 and 5 gave a sufficiently strong relationship to be clinically useful in predicting the size of 3, 4, and 5 before their eruption. Since this relationship does not involve the size of c, d, and e, the restriction in sample selection with reference to restorations in the deciduous teeth could be removed. By removing this restriction an additional thirty-five subjects became available for study. The larger sample ($N = 76$) provided a better basis for generalizing in terms of clinical use. The coefficient of correlation from the seventy-six cases, utilizing the best film of 4 and 5 available before their eruption, was $r = .87$. This figure is included in Table I. In Table II, the results have been expanded for prediction purposes in clinical situations.

The standard error of estimate for this relationship is 0.57 mm., which means the size of 3, 4, and 5 can be predicted before their eruption within 0.57 mm. for two-thirds of the cases, and the error of prediction will not exceed 1.1 mm. on more than one child

TABLE II

A TECHNIQUE FOR ESTIMATION OF THE SIZES OF MANDIBULAR CUSPIDS AND BICUSPIDS

Sum the maximum mesial-distal diameters of one permanent mandibular central and one lateral incisor with the diameter of the unerupted first and second bicuspids measured on the intraoral film of the same side. Enter this figure as the measured value to estimate the sum of the widths of the cuspid and bicuspids.

This estimate should be accurate within 0.6 mm. for 68% of the cases, within 1.1 mm. for 95% of the cases, and within 1.7 mm. for 99% of the cases.

Note: These data are valid only when a 16 inch cone is used on the dental x-ray machine.

measured value	estimated tooth size
23 mm.	18.4 mm.
24	19.0
25	19.7
26	20.3
27	21.0
28	21.6
29	22.3
30	22.9

$N = 76$
$M(x) = 20.96$ mm.
$S.D.(x) = 1.14$
$M(y) = 26.98$
$S.D.(y) = 1.53$
$r(xy) = .868$
$X = .6474Y + 3.493$
$S.E.\ est. = .568$

in twenty. The error of prediction will be as great as 1.7 mm. one time in 100. The index of forecasting efficiency[8] is 50 per cent. This represents an improvement of more than 25 per cent over methods previously suggested.

For the sample under study the maximum error of prediction from the proposed technique was 1.2 mm. Corresponding maximum errors were 2.8 mm. with the Carey chart, 2.3 mm. with the Ballard & Wylie chart, and 3.9 mm. from x-ray measurements of 3, 4, and 5 only.

Recommendation of this technique presupposes the use of a cone on the dental x-ray machine which gives a 16 inch skin-target distance. We have no information regarding relationships when using other cones. We obtained findings from use of films taken at eight years of age, irrespective of their quality, except for two individuals in whom the cuspids were erupting early. For these two, films taken at seven and one half years were used. The correlation coefficient, as shown in Table I, is $r = .82$. This would indicate slightly less efficiency in predicting from films taken at the younger ages, especially when possibility of retakes of poor films is excluded.

In mixed dentition analysis, the estimated size of 3, 4, and 5 can then be compared with the space available for their eruption. This space available can be obtained by measuring from the mesial surface of the mandibular permanent molars to the distal of the lateral incisors with a Boley gauge on which the measuring blades have been ground to a fine edge. For alignment of the teeth, compensation must then be made for incisor crowding or spacing, improper incisor inclination, plus incisal rotations. In ascertaining space for alignment, the potential mesial shift of the molars should also be considered.

Table III presents singly, and in combination, the difference in tooth size found between c, d, and e, and their permanent successors. Clinically, the most significant figures are the values obtained for the difference in size between the combined widths of c, d, and e, and 3, 4, and 5. On the average, the combined width of the three permanent teeth was 2.1 mm. smaller than that of the three deciduous teeth.

Carey[5] has pointed out the wide individual variation that exists between these deciduous and permanent teeth. This is consistent with the correlation coefficient ($r = .56$) noted in Table I, as well as the 1.1 mm. standard deviation seen in Table III. The range of this difference extended from 0.1 mm. in one case to 4.4 mm. for another child.

This is equivalent to some children

TABLE III

Analysis of the difference between the mesial-distal widths of 3, 4, and 5 minus the mesial-distal widths of c, d, and e in the mandibular arch, for 41 cases.

Tooth Widths	*Mean*	*S.D.*	*Range*
3 - c	+ 1.01 mm.	.39 mm.	+ .2 to + 2.0 mm.
4 - d	— .60 mm.	.48 mm.	+ .4 to — 1.6 mm.
5 - e	— 2.55 mm.	.42 mm.	— 1.7 to — 3.3 mm.
3, 4, 5 - c, d, e	— 2.13 mm.	1.05 mm.*	— .1 to — 4.4 mm

*Standard error of standard deviation is 0.11 mm.

showing no change in tooth size during the transition from the mixed to permanent dentition, while others show almost a 9 mm. decrease in tooth structure from the mesial surface of one first permanent molar around to the mesial surface of the opposite mandibular molar. Such a difference between the size of c, d, and e and 3, 4, and 5 is of clinical importance as some cases of extreme crowding in the mixed dentition in which serial extraction seems indicated will ultimately have sufficient room for alignment of the incisors plus space for 3, 4, and 5. Thus, the proposed predictive chart constitutes an improved aid in identifying such cases. The predictive chart is, of course, useful in mixed dentition analysis whenever c, d, or e has been prematurely lost.

Summary

1) The sizes of the mandibular cuspid and bicuspids were studied in relation to several variables.

2) From these relationships, it was possible to select a better technique for estimating the size of these teeth before their eruption. This involves measuring a mandibular permanent central and lateral plus the sizes of the x-ray images of the two unerupted bicuspids on the same side using a 16 inch cone on the x-ray machine. The index of forecasting efficiency for this technique shows a 25% improvement over previously suggested methods.

3) The variability found between the combined widths of the deciduous molars and cuspid and their permanent successors ranged from 0.1 mm. to 4.4 mm. The standard deviation of this difference in size between the two groups of teeth is decidedly greater than the standard error of estimate of the technique proposed for estimating the sizes of the unerupted cuspid and bicuspids.

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In Memoriam

Lynn Carter Wilkinson died in Milwaukee, Wisconsin on March 14, 1958. An only child, he was born in Cypress, Illinois. When Wilkie was three years old, his father was killed in an accident; his mother died when he was eleven years of age. Reared by an aunt, he secured all of his education through his own efforts.

Upon the completion of his high school years, Wilkie took his pre-dental training at the University of Illinois and was graduated from its College of Dentistry in 1930. In January 1931 he enrolled in the second class in the Department of Graduate Orthodontia, University of Illinois, completing the course in 1932 with a Master of Science degree.

Wilkie established his orthodontic practice in Milwaukee in 1933 and was still there at the time of his passing. He was a member of the local, state, and national dental societies, the Edward H. Angle Society of Orthodontia, Theta Chi and Beta Kappa social fraternities, and Psi Omega dental fraternity.

Wilkie was active in many conservation groups. An avid gun fan, he never missed a chance to go shooting. He was past president of the Milwaukee Gun Club and a member of the Waukesha Gun Club. He belonged to the Shorewood Men's Club and the Roundy Memorial Baptist Church to which he gave a great deal of his time.

His orthodontics were careful, sincere and meticulous. He took his part in the orthodontic society in a quiet, unobtrusive manner. Although he seldom commented during meetings, when he did, it was well worth one's full attention.

Surviving are his wife, Ruth, a fourteen year old daughter Leslie, and a son Carter who is a student at Northwestern University.

A.G.

The Angle Orthodontist

A magazine established by the co-workers of Edward H. Angle, in his memory . . .

Editor: Arthur B. Lewis.

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Vol. XXVIII, No. 4 October, 1958

Index to Authors

Index

The Angle Orthodontist

Instructions to Contributors

The author should submit the original typed copy of the manuscript, double-spaced on bond paper. The author's name and city of residence should appear immediately after the title, and the street address should appear at the end of the article.

Do not use symbols to indicate teeth; in *tables* teeth may be designated as U-1 or L-6, but in the text names of teeth should be fully written out.

Line drawings should be prepared in India ink on white stock; the width of lines and the size of lettering should take into account the fact that most illustrations are reduced in size in the engraving process. Photographs should be sharp, glossy prints of adequate size, *unmounted and kept separate from the text.* At the discretion of the editor, illustrations will be reproduced either as single column cuts of approximately 2¼ inches in width, or a double column cuts of 4¾ inches in width. The height of the cut may vary, but contributors should be keep in mind that proportionate reduction or enlargement of illustrations affects all dimensions, and that arrangement of material should be such that awkward proportions are avoided and no loss of clarity results.

The Frankfort plane should appear in cephalometric tracings, and wherever possible should provide the basis of orientation of illustrative matter portraying the face, whether it be films, tracings or facial photographs.

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